

SORGHUM AND COWPEA GENOTYPES FOR DRYLAND INTERCROPPING WITH LAND MANAGEMENT AND NITROGEN NUTRITION

**Thesis submitted in part fulfilment of the requirements for the award of the
degree of Doctor of Philosophy in Agronomy
to the Tamil Nadu Agricultural University
Coimbatore**

By

V VEERABADRAN

(ID Number 366)

**DEPARTMENT OF AGRONOMY
CENTRE FOR SOIL AND CROP MANAGEMENT STUDIES
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE - 641 003**

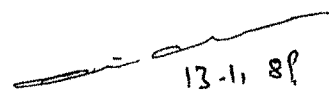
1989

C E R T I F I C A T E

This is to certify that the thesis entitled "SORGHUM AND COWPEA GENOTYPES FOR DRYLAND INTERCROPPING WITH LAND MANAGEMENT AND NITROGEN NUTRITION" submitted in part fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY IN AGRONOMY to the Tamil Nadu Agricultural University, Coimbatore, is a record of **bona fide** research work carried out by Mr.V. VEERABADRAN under my supervision and guidance. No part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other titles. The work has not been published in part or full in any scientific or popular journal or magazine.

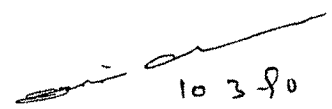
Place: Coimbatore

Date : 13 11 89


13-11-89
(Dr.S. SUBRAMANIAN)
Chairman

APPROVED BY

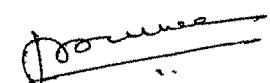
Chairman

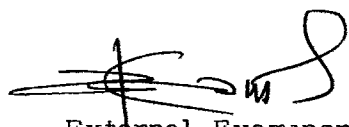

10 3 80
(Dr.S. SUBRAMANIAN)

Members

(Dr.R. KULANDAIVELU)


(Dr.G.V. KOTHANDARAMAN) 10/3/80


(Dr.N. NATARAJARATNAM)


External Examiner

ABSTRACT

ABSTRACT

SORGHUM AND COWPEA GENOTYPES FOR DRYLAND INTERCROPPING WITH LAND MANAGEMENT AND NITROGEN NUTRITION

By

V. VEERABADRAN

Degree : Doctor of Philosophy (Agriculture) in Agronomy

Chairman : Dr.S. Subramanian,
Professor and Head,
Regional Research Station,
Tamil Nadu Agricultural University,
Aruppukkottai - 626 107.

Year : 1989

Intercropping leads to increased productivity and stability in drylands. Agronomic manipulations such as selection of genotypes of component crops, moisture and nutrient management enhance the advantages of intercropping. Agronomic investigations on these aspects in rainfed sorghum-cowpea intercropping were conducted during 1983-86 at Tamil Nadu Agricultural University, Coimbatore. Two sorghum genotypes differing in height and duration were intercropped with three cowpea genotypes of varying duration and growth habit. Land management practice of bed furrow sowing was compared with flat bed sowing. Nitrogen levels tried were 0, 20 and 40 kg ha⁻¹.

The growth and yield of sorghum genotypes - tall late (125 days) and early dwarf types - were unaffected by intercropping with cowpea genotypes of different duration and growth habit. Sorghum yield in intercropping was 95-103 percent of sole sorghum yield indicating its dominance and greater competitiveness in intercropping.

Grain yield of cowpea in intercropping was reduced and varied from 10-25 per cent of sole crop yield. However, distinct differences in yield potential under intercropping were observed among cowpea genotypes. The long duration (90-100 days) climbing cowpea gave higher yield in intercropping over medium duration (80 days) spreading cowpea and short duration (70-75 days) erect cowpea. High yield of cowpea in intercropping was associated with longer duration, tall canopy, larger specific leaf area, more pod production, smaller grains and high harvest index. The grain yield of intercropped cowpea was more with late tall sorghum than with early dwarf sorghum due to avoidance of overlap of critical stages of resource requirement between the component crops.

Soil moisture content did not vary much between flat bed and bed furrow systems. However, sorghum yield was higher in bed furrow probably due to guided drainage under heavy rainfall in early season. Cowpea yield was not affected by sowing in flat bed or bed furrow.

The response of sorghum to applied nitrogen was similar in sole crop and intercropping with cowpea. Increase in intercropped sorghum yield with every increment of fertilizer N indicated the absence of 'legume effect' on cereal.

The total yield advantage of sorghum-cowpea intercropping system was 8-27 percent higher (LER=1.08-1.27) over sole sorghum. The combination of late tall sorghum with long duration climbing cowpea resulted in higher yield advantage and greater monetary returns than other combinations. Income stability through intercropping was evident from the minimisation of loss in intercropping through cowpea yield when sorghum yield was lost due to untimely rainfall at flowering. Sowing in bed furrow caused a marginal increase in LER of intercropping system. Nitrogen application substantially improved the yield advantage of sorghum-cowpea intercropping (LER = 1.21-1.36).

Water use was slightly higher in sorghum-cowpea intercropping than sole sorghum due to greater depletion of soil moisture. Consequently intercrop advantage was higher under adequate soil moisture availability resulting from normal well distributed rainfall. The estimated crop water use by sorghum-cowpea intercropping system varied from 191 to 309 mm depending on intercrop combinations and rainfall pattern.

The yield and monetary returns from sorghum-cowpea intercropping in drylands can be increased through the combination

of tall 125 days sorghum and 90-100 days climbing cowpea and application of 40 kg N ha⁻¹ to intercropping system. Bed furrow sowing would be advantageous when heavy rains in early season are anticipated.

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

The author wishes to express his deep sense of gratitude and indebtedness to the chairman of the Advisory Committee, Dr.S. SUBRAMANIAN, Professor and Head, Regional Research Station, Tamil Nadu Agricultural University, Aruppukkottai, for his expert guidance and valuable advice during the course of the investigation and preparation of the thesis.

The author is deeply indebted to the members of the Advisory Committee, Dr.G.V. KOTHANDARAMAN, Dean, Post-Graduate Studies, Tamil Nadu Agricultural University, Coimbatore, Dr.R. KULANDAIVELU, Professor of Agronomy, Irrigation Management Training Institute, Tiruchi, and Dr. N. NATARAJARATNAM, Dean, Pandit Jawaharlal Nehru College of Agriculture, Karaikal, Pondicherry, for their valuable advice at various stages of the study.

The author is thankful to Dr.S. SANKARAN, Director, Centre for Soil and Crop Management Studies, Tamil Nadu Agricultural University, Coimbatore, who was the chairman during the course work part of the programme.

Grateful acknowledgements are due to Dr.SP. PALANIAPPAN, Dean, Agricultural College, Coimbatore, whose book "Cropping Systems in the Tropics - Principles and Management", provided the inspiration for this investigation.

The help rendered to the author during the preparation of the thesis by Mr.P.RAJENDRAN and Mr.N.KEMPUCHETTY, Associate Professors of Agronomy, Mr.R.VENKATASAMY, Mr.K.SIDDHESWARAN, Mr.C.CHINNUSAMY and Mrs.C.JAYANTHI, Assistant Professors of Agronomy, Tamil Nadu Agricultural University, is gratefully acknowledged.

The perseverance and encouragement by the author's wife, KUMARI and sons, KANNAN and GANESH, enabled him to complete the thesis successfully despite many hardships.

C O N T E N T S

CHAPTER	TITLE	PAGE
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	6
3	MATERIALS AND METHODS	35
4	RESULTS	61
5	DISCUSSION	133
6	SUMMARY AND CONCLUSIONS ..	178
	REFERENCES	
	APPENDICES	
	PLATES	

LIST OF TABLES

TABLE NUMBER	TITLE	PAGE
3.1	Soil characteristics	37
3.2	Characters of sorghum genotypes	38
3.3	Characters of cowpea genotypes	39
3.4	Dates of sowing and harvest of crops	48
4.1	Sorghum height at harvest	62
4.2	Leaves per plant in sorghum	64
4.3	Leaf area index of sorghum	66
4.4	Dry matter production per plant in sorghum	67
4.5	Sorghum dry matter production at harvest	69
4.6	Sorghum ear length	70
4.7	Sorghum grain weight per ear	72
4.8	Sorghum grain yield	74
4.9	Sorghum grain yield under nitrogen levels	76
4.10	Sorghum grain yield under land management and N levels	76
4.11	Sorghum straw yield	77
4.12	Nitrogen uptake by sorghum	79
4.13	Cowpea height and DMP per plant	81

LIST OF TABLES (CONTINUED)

TABLE NUMBER	TITLE	PAGE
/ 4.14	Cowpea DMP at harvest	82
/ 4.15	Cowpea pods per plant	85
/ 4.16	Cowpea pod length	87
/ 4.17	Cowpea grains per pod	88
/ 4.18	Cowpea grain test weight	89
/ 4.19	Leaf area and weight per plant and specific leaf area of cowpea	91
/ 4.20	Cowpea grain yield	93
4.21	Cowpea grain yield under N levels	95
4.22	Cowpea grain yield under land management and N levels	95
/ 4.23	Cowpea haulms yield	97
/ 4.24	Nitrogen uptake by cowpea	99
/ 4.25	Total DMP in sole sorghum and sorghum- cowpea intercropping	100
4.26	Total dry fodder yield	102
4.27	Total uptake of nitrogen	103
4.28	Weed dry weight	105
/ 4.29	Harvest index of component crops	107

LIST OF TABLES (CONTINUED)

TABLE NUMBER	TITLE	PAGE
4.30	Dry matter distribution between plant parts	108
/ 4.31	Available soil moisture content (1983-84)	110
/ 4.32	Available soil moisture content (1984-85, 1985-86)	111
4.33	Soil moisture content in flat bed and bed furrow	113
/ 4.34	Soil moisture balance	114
/ 4.35	Crop ET and water use	115
4.36	Actual yield of component crops to expected yield	117
/ 4.37	Land equivalent ratio of intercropping	119
/ 4.38	Competitive ability of component crops	122
4.39	Cost and returns	124
4.40	Correlation between yield and growth characters of cowpea sole crop (1983-84)	126
4.41	Correlation between yield and growth characters of intercrop cowpea (1983-84)	127
4.42	Correlation between growth characters and yield of intercropped cowpea (1984-85, 1985-86)	128
4.43	Correlation between sorghum growth characters and yield of intercropped cowpea	130

LIST OF TABLES (CONTINUED)

TABLE NUMBER	TITLE	PAGE
4.44	Correlation between cowpea growth characters in sole cropping and intercropping	130
4.45	Regression of growth characters of cowpea and sorghum on the competition ratio of cowpea	131
4.46	Correlation of competition function values with actual yield of component crops	132

LIST OF FIGURES

FIGURE NUMBER	TITLE	PAGE
3.1	Layout - 1983-84	42
3.2	Layout - 1984-85, 1985-86	43
3.3	Sowing in flat bed and bed furrow	46
5.1	Rainfall distribution and crop duration	135
5.2	Pods per plant and intercrop cowpea yield	143
5.3	Dry matter and grain yield of intercrop cowpea	144
5.4	Height and yield of intercrop cowpea	146
5.5	Cowpea sole crop yield and intercrop yield	146
5.6	Sorghum canopy characters and cowpea competition ratio	150
5.7	Estimated evapotranspiration and actual water use	158
5.8	Time course of soil moisture depletion	160
5.9	Time course of soil moisture depletion	161
5.10	Sorghum grain yield with N levels in sole and intercropping	167
5.11	Regression of component crop LER on system LER	172

LIST OF APPENDICES

No.	DETAILS
I	Weather during the cropping period
II	Estimated soil moisture balance

LIST OF PLATES

No.	DETAILS
1	General view of the experimental field
2	Sorghum Co 25 intercropped with cowpea Co 1
3	Sorghum Co 25 intercropped with cowpea Co 4
4	Sorghum Co 22 intercropped with cowpea Co 1
5	Sorghum Co 22 intercropped with cowpea Co 4

INTRODUCTION

1. INTRODUCTION

The productivity of crops from the drylands of semi-arid tropics is low and uncertain. The primary limitation is the lack of an assured supply of available soil moisture throughout the cropping season; the major cause of this is the erratic distribution of rainfall. Many other factors such as low soil fertility also compound the intensity of the effect of low soil moisture availability on the productivity and income from drylands.

Cropping decisions by dryland farmers have therefore centered around the minimisation of the risks caused by uncertain rainfall. Intercropping has long been recognised as a kind of biological insurance against risks under aberrant rainfall behaviour (Singh and Jain, 1984). A substantial research effort to understand and improve the potential benefits of intercropping is therefore of great value to many small and marginal dryland farmers.

Early intercropping research often examined quite a large number of combinations to assess the compatibility of various crop species for intercropping. However, as we go for more detailed research to promote the advantages of intercropping, it may be necessary to focus on a few promising combinations (Willey, 1981) such as sorghum-cowpea intercropping.

Sorghum, the major crop in dryland cropping systems, is often intercropped with pulses such as pigeonpea, urdbean, mungbean,

and cowpea. Among the short duration pulses, cowpea has been found to be well adapted for intercropping with sorghum (Balasubramanian, 1983). Apart from examining the compatibility of the two crops, research is also needed to improve the magnitude of advantages from rainfed sorghum-cowpea intercropping.

The potential cause of yield advantage in intercropping is the better use of available environmental resources - light, water and nutrients (Palaniappan, 1985). An improvement in the availability of these resources and minimisation of the competition for resources between the component crops will improve the advantages of intercropping. To achieve this objective, Willcy(1981) suggested that agronomic studies on intercropping have to be taken up on plant population and spatial arrangements, moisture and nutrient management and evaluation of genotypes of component crops.

Just as different crops differ in their compatibility, the various genotypes of a given crop may also exhibit varying degree of adaptability to intercropping situation. Since the behaviour of mixed stands is not predictable from the behaviour of pure stands (Harper,1963), it may not always be correct to rely on the behaviour of genotype under sole cropping as a true index of its potential under intercropping. This suggests that intercropping performance of . genotype of the component crops must, at some stage, be evaluated actually in that intercropping system itself. With the multiplicity of genotypes of both sorghum, and cowpea, this approach

would involve trying out every variety combination and that would be unwieldy and time consuming. Ideally, such a testing should involve the identification of suitable plant characters of both component crops which minimise intercrop competition and maximise complementary effects. It can also serve as a basis for meaningful selection as and when new varieties of the crops are released.

Agronomic studies in intercropping must seek to understand how in practice intercropping yields can be maximised. Besides genotype evaluation, other aspects which merit consideration in this regard include moisture conservation and nutrient management. Intercrop advantages depend mainly on the competitive ability of component crops for use of the available resources. The supply or lack of these resources is then bound to have a significant effect on the performance of the component crops. Measures to alleviate moisture and nutrient stress can thus be expected to enhance the advantages of sorghum-cowpea intercropping.

Soil moisture availability is a major limiting factor for dryland crop productivity. With the combined population of a sorghum cowpea intercropping system exceeding that of sole cropping, there may be a greater demand for soil moisture. Measures to conserve soil moisture, may therefore, help to improve upon intercropping advantage. The land shaping technique of bed furrow is reported to provide many advantages besides conserving more rainfall in soil

profile. With such improved water resources development techniques available, there has to be an integration of cropping system with land management practices.

Interactions in intercropping situations may necessitate a modification in nutrient management from that for sole cropping. With higher production per unit area envisaged in intercropping total nutrient removal may increase; spatial and temporal differences between component crops may improve the use efficiency of soil and applied nutrients; the possible contribution of fixed nitrogen by legume may permit a reduction of fertilizer nitrogen. Recent research has highlighted the importance of integrated nutrient management system involving fertilizers and legume intercropping as a cost effective nutrient management practice for dryland crops. These aspects of nutrient management have to be evaluated in sorghum - cowpea intercropping to evolve an efficient nutrient management technology.

With this background this study was undertaken to evaluate the performance of rainfed sorghum - cowpea intercropping system as influenced by the genotypes of component crops, land management practices and nitrogen management. The broad objectives of the study are the following:

- * To evaluate the compatibility of sorghum and cowpea genotypes in intercropping
- * To identify plant characters of the component crops that promote intercropping advantages

- * To evaluate the effect of land management on the productivity of sorghum - cowpea intercropping
- * To study the effect of nitrogen nutrition in sorghum-cowpea intercropping.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during 1983 through 1986 to evaluate the advantages of rainfed sorghum-cowpea intercropping system as influenced by the genotypes of the component crops, land management for moisture conservation and nitrogen application. The aspects of importance in such a study include the compatibility of sorghum and cowpea for intercropping, the various advantages of intercropping and the mechanisms causing these advantages. These mechanisms are likely to be influenced by changes in the genotypes of the component crops exhibiting differences in duration, plant type and other growth characters. Agronomic manipulations through choice of genotypes, land management and nitrogen supply may modify the extent of advantage of intercropping systems. The literature on these various aspects of intercropping are reviewed here.

2.1. Importance of intercropping research in drylands

The importance of intercropping in farming practice has long been recognised but it is only very recently that it has awakened the real interest among research workers. The main reason for this is undoubtedly the increasing evidence that intercropping can provide substantial yield advantages over sole cropping in a given season and stability in yield over different seasons. There is a growing appreciation of the need for some research emphasis specifically on intercropping in drylands. Such research should assess not only the

possible advantages of different intercropping systems but also how they arise and how they might be improved (Willøy, 1979 a).

When such indepth studies on intercropping are planned, it is preferable to focus attention on specific intercrop combinations which are likely to be most promising. Sorghum-cowpea intercropping is one such promising combination which requires detailed studies to evaluate its advantages, to understand the mechanism causing these advantages and to find out the means to improve the magnitude of the advantages.

2.2. Sorghum-cowpea intercropping - its importance in drylands

Sorghum (*Sorghum bicolor*) is a staple food and fodder crop of the drylands. Rainfed sorghum is very often intercropped with many pulses - long duration pigeonpea (*Cajanus cajan*), lab-lab (*lab lab niger*) or short duration cowpea (*Vigna unguiculata*), urd bean (*Vigna mung*), mungbean (*Vigna radiata*). The choice of the intercropped pulse would vary with the situation. In places where the rainfall is erratic in early season, a pulse like redgram which matures later than sorghum may be able to make better use of rainfall. But in places where the rainfall is uncertain in late season, short duration pulses like cowpea may be more suitable (Venkateswarlu, 1985).

Cowpea has been found to be a compatible intercrop with rainfed sorghum in many locations. Among the many sorghum based

intercropping systems compared in drylands at Coimbatore, sorghum-cowpea intercropping gave the highest total grain yield (Manicka sundaram, 1978). Cowpea as an intercrop with sorghum gave higher yield advantage than other pulses like urd bean, mung bean or cluster bean (Balasubramanian, 1983). In experiments by Andrews (1974) and Kasam (1976), cowpea as an intercrop caused no adverse effect on sorghum; it also helped to get additional returns (Rajat De and Singh, 1981). Even under limited rainfall situations, Allen and Obura (1983) were able to get better yields from sorghum-cowpea intercropping than from sole sorghum.

All this early research has brought out the compatibility of cowpea as an intercrop with sorghum; but very little efforts have been made to understand the mechanism of such advantages and to identify those aspects which need further improvement to enlarge upon the magnitude of advantages of sorghum-cowpea intercropping in drylands.

2.3. Intercropping advantages

The growing awareness of the importance of research in intercropping in drylands can be attributed to its potential for offering many advantages. Prominent among the benefits of intercropping is the higher output per unit area per unit time which is very crucial in small farms. Stability of production in intercropping provides an insurance against adverse environmental condition in agroclimatologically unstable regions like the semiarid tropics (Singh and Jha, 1984).

2.3.1. Yield advantage in intercropping

Yield advantages in intercropping can be classified into three categories. In some instances, the base crop gives 'full' yield similar to the sole crop and some additional yield is obtained from the intercrop. In other situations, the combined intercrop yield may exceed the higher sole crop yield. A third possibility is where the combined intercrop yield may exceed the combined sole crop yield (Willey, 1979a). In all these situations, the total yield from intercropping is always more than either of the sole crops. Higher total yield has been reported from many intercropping experiments involving sorghum and cowpea (Andrews, 1974; Singh, 1977; Manickasundaram and Palaniappan, 1978 ; Balasubramanian, 1983; Faris et al., 1983; Venkateswarlu, 1983; and Umrani et al., 1984). These results have conclusively established the compatibility of sorghum and cowpea for intercropping in drylands.

Since sorghum is valued for its grain and straw, the expectation in sorghum-cowpea intercropping systems, therefore, must be to get 'full' yield of the staple millet of sorghum and higher total grain yield over sole crop of sorghum or cowpea. Any research programme in this system has to focus on this objective.

2.3.2. Sorghum yield in intercropping

In intercropping studies with sorghum, instances of increase in intercropped sorghum yield over sole crop yield are many. Yield

increase of intercropped sorghum over sole cropped sorghum ranging from 8 to 34 per cent has been reported with different pulses by Singh(1977). Higher yield of sorghum in intercropping with cowpea than sole sorghum was reported by Thangasamy (1983). But there are also some experimental results in which intercropped sorghum yielded less than the sole crop (Gebrakidan, 1977; Tarhalkar and Rao, 1981). In the all India co-ordinated sorghum improvement project trials, conducted all over India, in several years at many locations, sorghum yield turned out to be higher in intercropping than sole cropping. In some locations, however, a reduction in the yield of intercropped sorghum was observed (Singh and Jha, 1984). This was obviously due to the variations in the associated crops, soil conditions and rainfall pattern between locations.

The near 'full' yield of intercropped sorghum is a sign of its dominance in any intercropping system and its higher competitive ability. This points towards the need for proper manipulation of sorghum growth through suitable agronomical measures so as to create a favourable environment for the associated crop to give a reasonably good performance in intercropping, so that total yield advantage is ensured.

2.3.3. Cowpea yield in intercropping

Since cowpea population in intercropping system is usually less than that of sole crop, the yield of intercropped cowpea can

only be lower than sole cowpea. Cowpea grown in association with sorghum in rainfed conditions recorded only 30-40 per cent of its sole crop yield (Selvaraj, 1978) and in association with maize, cowpea as an intercrop produced lesser yield than its pure stand (Ahmed and Gunasena 1979; Adetiloye, 1980; Francis et al. 1982; Remison, 1982). As much as 48 per cent reduction in cowpea yield in association with maize was observed by Fawusi et al. (1982).

A lower yield of cowpea in intercropping can not be fully explained by the population factor alone; There may be other aspects of cowpea growth which affect its performance in intercropping. An understanding of these growth aspects would help to favourably manipulate them for improving the contribution of cowpea to the overall yield advantage of sorghum-cowpea intercropping.

2.3.4. Stability of yield and income in intercropping

It is often said that improved stability of yield is one of the major reasons why intercropping continues to be an extremely important practice in areas of greater risk as in rainfed farming. Here intercropping is considered as a kind of biological insurance against total crop failure under aberrant weather conditions (Singh and Jha, 1984). The basis for this is that if one crop fails or grows poorly, the other component crop can compensate and such compensation cannot occur if the crops are grown separately.

Analysis of yield levels of sorghum-legume intercropping systems over many years revealed that the coefficient of variation of the yield was lesser in intercropping than the sole crop of sorghum or legume (Rao and Willey, 1980). Lower coefficient of variation is an index of more stable yields. In monetary returns as well, sorghum legume intercropping proved to be better than sole cropping of sorghum as observed by Kunasekaran et al. (1980). Analysis of a large number of experiments on sorghum-legume intercropping revealed lesser variation in returns from intercropping over many years, confirming its stability value (Singh and Jha, 1984).

However, the process of stability is not likely to be consistent in all combinations of crops or their genotypes. Thus, there is a need to determine the extent of stability in production and income arising out of sorghum-cowpea intercropping in drylands.

2.4. Biological basis for intercropping advantages

The most important biological aspect of intercropping is the interaction between the component crops when they are grown in close association. This interaction may be complimentary leading to advantages but can also be competitive resulting in stress and disadvantages. An understanding of the basis for this interspecies interaction in intercropping is essential to make necessary agronomic manipulations to maximise intercropping advantages.

Better overall use of available resources is often claimed to be the major complimentary mechanism leading to yield advantage in intercropping. When two crops are grown in combination they are able to compliment each other because of the differences in their use of growth resources (Willey, 1979a). Temporal differences in growth pattern over time (duration) and spatial complementarity through combined leaf canopy and combined root system may cause better use of environmental resources of light, nutrients and water (Palaniappan, 1985).

2.4.1. Above ground interactions - light use in intercropping

Light is a resource that is instantaneously available and has to be instantaneously intercepted and utilised; it cannot be stored and used as per demand (Donald, 1963). Because of this it was emphasised earlier that light was probably the most important factor in intercropping advantages. Efficient use of light by intercrop canopy was recorded in many intercropping experiments (Baker and Yusuf, 1976; Natarajan and Willey, 1981).

Trenbath (1981) observed that the overall light use efficiency could happen in two ways - through a greater interception on incident light or through a better efficiency of conversion of intercepted light. Mafra *et al.* (1981) identified the greater interception of light by intercrop canopy as the cause for the total yield advantage. But, the greater efficiency of conversion of intercepted light was quoted as the cause for intercropping advantage

by Reddy et al. (1980). In sorghum-pigeonpea intercropping, both the above mechanisms contributed to yield advantage, as reported by Natarajan and Willey, (1981).

Light use efficiency in intercropping can be expected when crops with differential response to light viz., a top canopy of high light requiring crop and a bottom canopy of low light requiring crop are grown together (Crookston and Kent, 1976; Reddy and Willey, 1981). Such a situation exists when a C_4 plant like sorghum and a C_3 plant like cowpea are grown together in intercropping.

2.4.2. Below ground interactions

From the many intercropping studies carried out, more information is available on above ground interactions; but information on below ground interactions such as root growth, nutrient dynamics and moisture use are few (Palaniappan, 1985). But the importance of below ground interactions cannot be minimised because in some experiments intercropping advantages were observed only when there was interaction between the root systems of the component crops (Snaydon and Harris, 1981).

2.4.2.1. Nutrient uptake

An important consequence of higher yield in intercropping was a commensurately greater uptake and removal of nutrients as

observed by several workers (Dalal, 1974; Natarajan and Willey, 1980, Singh, 1983). Higher nutrient uptake in intercropping may be due to many reasons. The component crops may exploit different soil layers and extract nutrients from a larger soil volume through the combined root system; they may require different nutrients and they may be able to extract the same nutrient from different forms in the soil (Willey, 1979a, Snaydon and Harris, 1981). Another possible mechanism could be the interaction between rhizosphere microorganisms of component crops benefitting nutrient uptake (Shantharam and Rangaswamy, 1967, Christie et al., 1974; Kibani et al., 1976).

In legume non-legume association, a very important mechanism of complementarity in nutrient use is the legume effect i.e. the ability of legume to fix atmospheric nitrogen and release it later to associated non-legume. The conclusive evidence for legume effect is the higher yield of non-legume in association with legume than its sole crop yield. Many experiments on legume non-legume intercropping since very early days have demonstrated this advantage (Agboola and Fayemi, 1972; Wien and Nangju, 1976; Soundararajan and Palaniappan, 1979; Gangwar and Kalra, 1979; Nair et al., 1979 ; Rajat De and Singh, 1981) However, the extent of contribution and the factors affecting nitrogen fixation by the legume and the current transfer of N to non-legume are not very clear and there is still a lot of inconsistency about legume effect in intercropping.

Deliberations at the International Workshop on intercropping held in 1979 highlighted this aspect and outlined the need for further research to maximise this effect.

2.4.2.2. Water use

Water use and its efficiency in intercropping has received less attention than nutrient uptake. However, better water use in intercropping can be a logical cause of yield advantage in semi arid tropics where water is the most limiting resource (Baker and Norman, 1975). Here again, the advantage may be due to greater water extraction or higher use efficiency of available water or both. Wahab (1978) reported an increase in the total water requirement of sorghum cowpea intercropping whereas in some other intercropping studies a higher water use efficiency was quoted as the cause of the advantage rather than a greater drain of available soil moisture (De et al., 1978; Krishnasamy and Palaniappan, 1979; Reddy et al., 1980). The high water use efficiency recorded in intercropping was due to reduction of evaporation loss from inter-row space by intercrop canopy and cycling of more water through transpiration from extended crop canopy in intercropping (Natarajan and Willey, 1981). The availability of water and its use efficiency would, therefore, decide the relative advantages of intercropping under varying rainfall conditions in drylands.

Besides the better use of various resources like light, water and nutrient, certain other mechanisms also were found to

be related to the yield advantage in intercropping. Better weed control was often attributed to be a cause for intercropping advantages. Many research workers have observed a suppression of weed growth in many intercropping systems; in maize + mungbean/cowpea (Bantilan and Harwood, 1974; Bantilan *et al.* 1974), in maize + soybean (Guleria and Singh, 1979), in millet + cowpea (ICRISAT, 1977), in sorghum + urdbean/cowpea (Boopathi Babu, 1978), in sorghum + mungbean/cowpea (Moody, 1978), in sorghum + legumes (Abraham and Singh, 1984). The reduction in weed intensity in intercropping was attributed to the high population pressure of the component crops together (Rao and Shetty, 1976; Shetty and Rao, 1981). However, the weed suppressing ability of the intercropping system was found to be dependant on such factors as the component crops, their genotypes, and soil moisture and fertility status (Shetty and Rao, 1979; Moody and Shetty, 1981).

2.5. Agronomic manipulations to increase complimentarity in intercropping

The inconsistency observed in results of intercropping experiments was attributed to the variation in plant architecture and growth habit (Remison, 1978a) or to management practices, particularly fertilizer application (Wijesinha *et al.* 1982). These factors have been shown to play an important role in the complimentarity of intercrops. So, suitable manipulation of these factors through agronomic techniques can help to minimise competition and improve complimentarity in intercropping. Such techniques which need investigation in sorghum-cowpea intercropping cover the aspects of

plant population and crop geometry, choice of genotypes of the component crops, moisture and nutrient management.

2.5.1. Genotypes of component crops and intercrop advantages

Selection of genotypes specifically suited to complex cropping system has received little priority so far. Two assumptions normally made in intercropping have precluded the need for such an evaluation. One is that all the genotypes of a crop perform similarly in intercropping and the other is that the performance of a given genotype in intercropping can be easily predicted from its sole crop behaviour. It is necessary to confirm or reject these hypotheses to avoid or include genotype evaluation as a topic of importance in intercropping research.

As early as 1963, J.L. Harper stated that the behaviour of mixed stands was not predictable from the behaviour of pure stands. It is well known that just as crops differ between species, the genotypes within a given crop species also differ in such temporal aspects as duration, growth rhythm and spatial aspects such as height, canopy display, branching habit, leaf area etc. (Rao et al., 1981). Since resource use in intercropping is a result of differences in temporal and spatial features, genotypes differing in such respects can be expected to exert varying degrees of competitive pressure and thereby cause differential effects on intercropping advantages. Therefore, intercrop performance cannot be expected to be constant over all combinations of the genotypes of the component crops.

For a dominant crop like sorghum, selection of genotype for intercropping based on sole crop performance may work well. Even here, differences can be expected. But genotypes of the dominated crops like legumes may perform in a manner altogether different from their sole crop performance because of the modified environment induced by the dominant crop. Very little is known on this aspect atleast for genotypes of the dominated crops and much more research is required. Therefore, Willey (1979b) suggested that the genotypes which are eventually to be used in a given intercropping must at some stage be evaluated in that situation itself. The aspects to be studied in such an evaluation would include duration, growth pattern, height, plant type and rooting pattern.

2.5.1.1. Genotype duration

Difference in genotype duration may be reflected in resource use efficiency in intercropping. Greater the duration difference between genotypes of component crops, lesser was the competition (Chinnappan and Palaniappan, 1980) and more was the yield advantage in intercropping (Francis et al. 1976; Baker, 1981).

The duration of genotypes of the base crop may affect the growth of both components in intercropping. An early maturing sorghum gave lower yield than a late variety in sorghum-cowpea intercropping (Gebrekidan, 1977). A reduction in millet duration allowed a higher yield of intercropped groundnut and pigeonpea in

studies at ICRISAT (1981) whereas soybean growth was reported to be good with longer duration sorghum (Tarhalkar and Rao, 1981).

The duration of the legume genotype might influence its competitive ability in intercropping. Longer duration genotypes of pigeonpea performed better than early maturing cultivars in intercropping with sorghum (ICRISAT, 1987b). In cowpea, there are indications of a shorter duration genotype giving more benefit to the cereal as indicated by the higher yield of the cereal with fodder cowpea than with grain cowpea (Balyan and Seth, 1985, Venkateswarlu, 1986).

In experiments conducted by Osiru and Willey (1972), combination of genotypes with specific duration proved to be more advantageous in sorghum-beans and maize-beans association. Beans variety of 85 days grown with 120 day variety of sorghum/maize gave the highest yield advantage (Willey and Osiru, 1972).

2.5.1.2. Plant type

Growth habits of cultivars such as height, canopy spread and plant architecture also influence intercropping advantages. Short statured sorghum genotype allowed better performance of pigeonpea than tall sorghum varieties (Rao et al., 1981, Rao and Willey, 1983), whereas, tall maize varieties were more compatible with beans and cowpea (Francis et al., 1976; Kitamura and Nashimura, 1979). Andrews

(1974) observed that a reduction in the height of the dominant cereal resulted in higher yield from associated crops. Even where duration difference was less, the difference in height between the genotypes caused more advantage (Willey and Rao, 1977; Baker, 1981).

Spreading or erect growth habit of genotypes may lead to considerable difference in the intercropping performance of legumes. Willey and Rao (1981) described the ideal plant type of pigeonpea for intercropping with sorghum as one that had compact growth in early stage and a spreading habit later. Pigeonpea with no basal branches was less sensitive to intercrop competition than genotypes with basal branches (Rao et al., 1981) and a spreading type of pigeonpea did better in intercropping (Tiwari et al., 1977). In groundnut, spreading genotypes gave the best intercropping performance with millets in studies at ICRISAT (1981). Tarhalkar and Rao (1981) reported that a bushy long duration pigeonpea reduced sorghum yield to a greater degree than an erect genotype.

In cowpea, differential adaptation to intercropping conditions were observed between spreading and erect genotypes. An erect cowpea genotype gave higher yield in sorghum based intercropping in high rainfall years but a spreading type performed better in low rainfall years (Stoop, 1981). In experiments conducted to study the effect of cowpea genotypes on maize yield in intercropping, Wien and Nangju (1976) concluded that an erect determinate cowpea

genotype exerted less competitive effect on maize than indeterminate types.

There is also some evidence to indicate that some of the mechanisms of intercropping advantage may be altered by genotype differences. Differential weed suppressing ability between genotypes of the same crop has been reported by many workers (Bantilan *et al.*, 1974; Rao and Shetty, 1976; Remison, 1978b and Shekhawat *et al.*, 1983). According to Trenbath (1981), even the penetration of light through canopy of the dominant crop could be manipulated by choice of genotypes to benefit the dominated crop and the identification of genotypes of the dominated crop possessing characters associated with tolerance to low light intensity would be very useful. Szeicz (1975) reported that by selecting genotypes adapted to the qualitative change in light occurring down the canopy, the light use efficiency in intercropping could be improved.

The experimental evidence so far presented bring out the scope of exploiting genotype differences to increase the advantages in intercropping system. The objectives of such an evaluation of genotypes in intercropping would be to identify those characters of importance in adaptation to the altered environment in intercropping so as to minimise competition stress (Bede Okigbo, 1981).

The ultimate objective of genotype evaluation in intercropping studies is to decide whether genotype selection for intercropping

can be made from the performance in sole cropping or in the intercropping system itself. In the opinion of Wien and Smithson (1981), such an identification of genotypes for intercropping should take the following progression. First, the intercrop system for which the genotypes are selected must be defined; then the system must be subjected to varying levels of resource supply so that truly adapted genotypes can be identified. In the screening process, genotypes differing in various aspects must be included so as to identify characters of importance in adaptation to intercropping situation. Thereafter, it is necessary to determine the extent to which the same characteristics are also expressed under sole crop conditions so as to decide whether selection of genotype for intercropping can be made from sole crop performance itself or has to be done only under actual intercrop situation.

2.5.2. Land management for moisture conservation in intercropping

2.5.2.1. Moisture availability and intercrop advantages

Environmental conditions can have marked effects on the competitive balance and final yield proportions of the component crops in intercropping. In drylands, rainfall variability from season to season is high and it might show a greater influence on yield of the crop in intercropping. Studies by Natarajan and Willey (1980) on the effects of moisture availability on yield advantages in intercropping revealed that differences in moisture regime may affect the competitive balance of the component crops.

Intercropping yields in general were more when moisture was not a limiting factor (Singh et al., 1978; Tomer and Saini, 1979; Singh, 1981). Maize-bean association gave more benefits in a wet season than in the dry season (Fisher, 1977) and greater yield advantages of sorghum - cowpea intercropping were realised under conditions without restriction in water (Mafra et al., 1981).

Stress for moisture in intercropping situations could affect the total yield advantage by reducing the relative contribution from the component crops depending on the stage of occurrence of moisture stress. In studies conducted at ICRISAT (1981), an early stress for moisture reduced the proportion of sorghum yield to total intercropping yield. Snaydon and Harris (1981) reported a reduction in legume component and a consequent decrease in total yield in intercropping due to deficiency of soil water.

The response to moisture stress might vary even between the genotypes of a crop. Babalola (1980) while studying water relations of cowpea genotypes observed that soil moisture stress reduced the yield of cowpea by 34 to 46 per cent and the yield reduction was more in semi-erect genotype than in spreading type. This suggests that under conditions of limited moisture supply in the drylands, the competition for moisture between sorghum and cowpea in intercropping would cause varying degree of response from cowpea genotypes.

2.5.2.2. Water requirement in intercropping

With the combined plant density of intercropping exceeding that of sole crop, an increase in water requirement is a distinct possibility. In many intercropping studies, an increase in water requirement over sole cropping was observed; in sorghum + cowpea (Wahab 1978), millet + groundnut (Reddy et al., 1980), mungbean + groundnut (Krishnasamy and Palaniappan, 1979) and in cowpea + pigeonpea (Hegde and Saraf, 1979). Therefore, conservation of more moisture in drylands can be expected to favourably influence the advantages of sorghum - cowpea intercropping.

2.5.2.3. Land management for moisture conservation

In rainfed lands, the run-off during rainy season may cause rain water to be lost. Land configuration such as basins, beds, furrows etc. may help to moderate the overland flow by reducing the velocity of run-off water (Sharma et al., 1982).

Among the various land management practices, the bed furrow configuration has many advantages. They are semi-permanent thus reducing recurring cost and the bed zone is less compact. During high intensity rains, the furrows can help guided drainage and prevent water stagnation. This is especially important for sorghum-cowpea system because both are sensitive to water stagnation. Cowpea was found to be extremely sensitive even to a short duration of submergence (Lal, 1979). With bed furrows, Sharma et al.

(1982) observed an improvement in the general environment for crop growth. Reduction in run-off and increased storage of soil moisture were observed in bed furrows over flat bed sowing by Chittaranjan *et al.* (1983) and Miranda *et al.* (1983).

Thiagarajan and Ramiah (1984) reported an increase in the yield of sorghum in bed furrow over flat bed sowing. In studies at Tamil Nadu Agricultural University, Coimbatore (Anonymous, 1982), intercropped cowpea yielded more in bed furrows than in beds.

In contrast, in many other experiments, however, no distinct yield advantage was caused by bed furrows over sowing in beds or ridges and furrows. In the onfarm collaborative research between ICAR and ICRISAT in shallow and medium deep vertisols, there were no noticeable differences in yields between flat bed sowing and bed furrow sowing (ICRISAT, 1982). Krantz (1981) reported similar findings with maize in shallow to medium deep soils.

The contradictions observed on the relative efficiency of different land management practices may be due to differences in soil type and rainfall pattern. A further evaluation of the relative merits of sowing sorghum and cowpea in beds or bed furrows may therefore be necessary.

2.5.3. Nitrogen management in intercropping

Fertilizer management in intercropping acquires significance for many reasons. First of all, there is an anticipated increase in nutrient requirement by the combined population of the component crops exceeding that of a sole crop. Then, there is the competition for nutrients between the two crop species in intercropping. In cereal-legume intercropping, the management of nitrogen becomes more important due to the "legume effect" of contribution of fixed nitrogen to the nonlegume. The competition for N as well as the legume effect may necessitate a change in the quantity of fertilizer N to be added to the cereal legume intercropping system.

2.5.3.1. Fertilizer use and intercropping advantages

An important question to be asked here is whether intercropping advantages are affected by changes in nutrient availability and supply. There is a long standing belief that intercropping advantages occur only in low fertility situations (Willey, 1979b). In fact a decrease in the relative biological advantage of intercropping with increased rate of nitrogen application as indicated by lower LER values has been recorded in some intercropping experiments; in sorghum-pigeonpea system (Rego, 1981); in maize-soybean system (Searle et al., 1981) in millet-groundnut intercropping and in sorghum-cowpea system (ICRISAT, 1982).

Although there is some evidence that relative intercropping advantage may decrease with higher nitrogen application, the absolute yield advantages may be much greater at higher fertilizer levels because of higher yield achieved. This is as good a reason as any to recommend proper fertilizer input in intercropping (Rao and Willey, 1981). This is supported by the finding by Rego (1981) that at moderate levels of nitrogen both relative as well as absolute yield advantages in intercropping were more than in no fertilizer application.

Further, a very important consequence of higher yield in intercropping as observed by Rao (1985) was a commensurately greater uptake and removal of nutrients. So it seems logical that maintenance of high yields in intercropping is dependent on a corresponding fertilizer input. Thus, it is expected that in sorghum-cowpea intercropping system, the spatial complementarity between the two crops in nutrient use is likely to be affected by the supply or lack of one or more nutrients.

2.5.3.2. Response of component crops to fertilizer use

A further question asked is whether the response of individual crops to applied fertilizer N is different in intercropping from that in sole cropping. This is particularly important when nutrient requirement of component crops differ widely as in a legume non-legume system.

In many intercropping experiments, sorghum responded to fertilizer nitrogen in a manner similar to sole sorghum (Ahmed and Gunasena, 1979; Rego, 1981; Anonymous, 1982). But the legume performance was either depressed or not influenced by nitrogen applied to intercropping (Ahmed et al., 1976; Gangwar and Kalra, 1979; Choudhury and Misanger, 1981; Rego, 1981). Even the genotypes of a given crop could vary in their nutrient requirement and response to applied fertilizer (Saxena and Sheldrake, 1979; Sahrawat et al., 1982).

The differential response of a crop species to applied N between sole cropping and intercropping could be due to the competition between species. Wahua (1983) reported that in maize-cowpea intercropping, there was competition for N between maize and cowpea and this was reflected in the difference in uptake by the two crops in sole cropping and intercropping. These results suggest that care is necessary in designing nitrogen management practice so as to minimise competition for N and to get maximum benefit from both the component crops in intercropping.

2.5.3.3. Legume effect in intercropping

Another dimension to nitrogen management is added in legume-nonlegume intercropping where a possible contribution of fixed nitrogen by legume to non legume may necessitate a modification in nitrogen supply to intercropping as different from sole crop.

The potential transfer of fixed nitrogen from the legume to the non legume and a consequent saving in nitrogen fertilizer to be applied to intercropping was reported from some experiments (Singh and Singh, 1977; Sahrawat *et al.*, 1979; Soundararajan and Palaniappan, 1979; Narain *et al.*, 1980; Ramakrishna, 1984). But an overwhelming evidence did not indicate any current transfer of nitrogen from legume to nonlegume during growing season (Agboola and Fayemi, 1972; Henzel and Vallis, 1977; Selvaraj, 1978; Rego, 1981; Searle *et al.*, 1981; Anonymous, 1982; ICRISAT, 1982; Rao, 1985). Thus the question of contribution of nitrogen from legume to nonlegume in intercropping still remains unsolved. An examination of the factors influencing nitrogen fixation by legume in intercropping may probably explain the inconsistency in this issue. Thus the questions to be examined in nitrogen management for sorghum-cowpea intercropping include the effect of fertilizer N supply on intercropping advantages, the response of sorghum and cowpea to applied nitrogen and the possibility of a saving in fertilizer nitrogen due to the "legume effect".

2.5.4. Effect of integrated technology on intercropping advantages

The synergistic effect of many production factors applied together may lead to considerable improvement in yield. When variety, fertilizer and land management were integrated, the yield increase was double that of the sum of increase due to the same three steps applied singly (Krant, 1981). Improved genotypes,

high inputs and land management together gave much higher income than local genotypes with low level input supply and management (Ryan and Sarin, 1981). Hence, in rainfed sorghum-cowpea intercropping system also, the combination of compatible genotypes with suitable land management for moisture conservation and adequate nitrogen supply can be expected to bring in synergism.

2.6. Indices for evaluation of intercropping

2.6.1. Assessment of yield advantage

Different levels of yield advantages can be expected from varying combinations of crops and their cultivars. The index most commonly used to assess the yield advantage in intercropping is the land equivalent ratio.

Land equivalent ratio (LER) in its simplest form can be defined as the relative area of sole crop that would be required to produce the yields achieved by intercropping. Values of LER less than one, equal to one or greater than one indicate, respectively, a yield disadvantage, no difference or yield advantage. Different crops are put on a comparable basis through LER values. However, LER values indicate only relative effects of the physiological efficiency of intercropping vs sole cropping and some indication of absolute yield level is also needed (Willey, 1981).

2.6.2. Assessment of monetary advantages

The LER does not appear to be a valid measure of evaluating the revenue yielding worth of intercrops. In pulses, for example, because of high prices, even a small reduction in yield in intercropping may reduce LER only slightly but may cause much loss of monetary return. Along with LER, monetary value of total produce may be considered which will directly indicate the relative profitability of intercropping system (Choudhury, 1981).

2.6.3. Assessment of competition in intercropping

2.6.3.1. Aggressivity

Aggressivity is an index of the competitive abilities of the component crops. It gives a simple measure of how much the relative yield increase of one component is greater than that for the other component. An aggressivity value of zero indicates that the components are equally competitive. The dominant component will have a positive value of aggressivity and the dominated crop has a negative value. The greater the numerical value, bigger is the difference in competitive abilities and bigger the difference between the actual and expected yields. But aggressivity values do not give any indication of yield advantage in intercropping (Mc Gilchrist, 1965).

2.6.3.2. Relative crowding coefficient

The relative crowding coefficient (RCC) as proposed by de Wit in 1960 indicates the relative competitive abilities of the component crops and the existence of any advantage. Each component has its own coefficient which gives a measure of whether that component gives more or less yield than expected. If a component has a coefficient less than, equal to or greater than one, it means, it has produced less yield, the same yield or more yield than expected, respectively. The component with higher coefficient is the dominant one. The product of the coefficients of the two component crops will indicate whether there is any yield advantage or not. If the product is more than one, there is yield advantage; equal to one, no difference; and less than one means yield disadvantage (Willey, 1979a; Palaniappan, 1985).

2.6.3.3. Competition ratio

The competition ratio is a new function proposed by Willey and Rao (1980) as a measure of intercrop competition to indicate the number of times by which one component is more competitive than the other. The competition ratio (CR) could be useful in (i) comparing the competitive ability of different crops; (ii) measuring competitive changes within a given combination; (iii) in identifying plant characters associated with competitive ability and (iv) determining the competitive balance between components most likely to give maximum yield advantage. Competitive

ratio can be correlated with change in a given plant character. The major advantage of CR is that it takes care of the proportion of the space occupied by a component crop in intercropping. This advantage is not available in the LER concept.

2.6.3.4. Regression analysis

Breese and Hill (1973) found that the regression of intercrop yield over base crop yield was useful to determine the interaction between the competing species. By using regression values, they were able to identify the intercrop species which was more stable at varying levels of base crop productivity. Such an analysis will be particularly useful in evaluation of intercrop genotypes also.

The foregoing review of literature suggests that the complementarity and competition in sorghum-cowpea intercropping are likely to be strongly influenced by the choice of genotypes of the component crops. The relative performance of various combinations of genotypes will be further affected by varying moisture availability caused by different land management practices and also by the application of fertilizer nitrogen. This study was therefore planned to gain a better understanding of sorghum-cowpea intercropping as influenced by genotypes of the component crops, land management for moisture conservation and nitrogen application.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field experiments were conducted during 1983-86 at Tamil Nadu Agricultural University, Coimbatore to evaluate the complimentary and competitive aspects of rainfed sorghum-cowpea intercropping, as influenced by genotypes of component crops, land management systems for moisture conservation and nitrogen management. The details of the materials used and the methods adopted during the course of the study are described in this chapter.

3.1. Materials

3.1.1. Location

The experiments were conducted in Field No.36, Central Farm of Tamil Nadu Agricultural University, Coimbatore situated at 11°N latitude and 77°E longitude at an altitude of 426 meters above MSL.

3.1.2. Weather

The region is situated in semi arid tropics (Krishnan, 1988) with an annual rainfall of 644 mm in 49 rainy days. The normal rainfall during the cropping period (September - February) as estimated from data for the past 35 years is 402 mm in 26 rainy days. The actual rainfall during cropping season was 392mm in 19 days during 1983-84, 563 mm in 25 days during 1984-85 and 283 mm in 14 days during 1985-86.

The mean annual maximum temperature and mean annual minimum temperature of the place are 29.5°C and 19.9°C, respectively. The data on weather parameters recorded during the cropping period in the three years of experimentation are given in Appendix I.

3.1.3. Soil characteristics at the experimental site

Soil of the experimental field is medium deep (65 cm) black soil with sandy clay loam surface texture. The data on mechanical composition and physical and chemical properties of the soil are presented in Table 3.1. Maximum available water holding capacity in 60 cm depth was 97.7 mm. Analysis of available nutrient content of the experimental field prior to sowing during the three years showed that the soil was low in N, medium in P and high in K.

3.1.4. Crop and varieties

Two genotypes in sorghum were used in the study. Sorghum Co 25 (culture TNS 27 released in 1985) is a medium tall variety with a duration of 115-120 days. Its yield potential under rainfed conditions ranged from 1600 - 1900 kg ha⁻¹ in yield trials. Sorghum Co 22, released in 1982, is a dwarf type with short duration of 95-100 days. It recorded a grain yield of 1400-2000 kg ha⁻¹ under rainfed conditions. The plant characters of the genotypes of sorghum are furnished in Table 3.2.

Table 3.1. Soil characteristics

Particulars				
Physical properties				
Coarse sand	(%)	20.7		
Fine sand	(%)	28.2		
Silt	(%)	18.0		
Clay	(%)	32.1		
Soil depth	(cm)	0-15	15-30	30-45 45-60
Bulk density g cc ⁻¹		01.34	01.45	01.48 01.40
Total porosity	(%)	50.2	48.1	45.9 47.5
Hydraulic conductivity	(cm hr ⁻¹)	02.58	01.53	00.83 01.19
Field capacity	(%)	20.6	22.1	21.9 21.2
Wilting point	(%)	08.9	10.4	10.1 09.7
Available water holding capacity (mm/60 cm)		97.7		
Chemical properties				
Particulars		83-84	84-85	85-86
Available N	kg ha ⁻¹	132	128	100
Available P	kg ha ⁻¹	12.6	11.8	12.3
Available K	kg ha ⁻¹	565	480	582
Organic carbon	(%)	0.4	0.37	0.37
EC	m.mhos cm ⁻²	0.38	0.32	0.42
pH		8.2	8.2	8.4

Three cowpea genotypes viz. Co 1, Co4, CoVu 7 were included in the study during 1983-84. Due to very low yield obtained in the first year (20-32 kg ha⁻¹) in intercropping, CoVu 7 was not included during the subsequent years. Only two genotypes viz., Co 1 and Co 4 were evaluated during 1984-85 and 1985-86. Cowpea Co 1 is a tall climbing type with a duration of 90-100 days. Cowpea Co 4 is a spreading type of 75-80 days duration. Cowpea CoVu 7 is a short erect type with a duration of 70-75 days. The details on plant characters with yield potential of the three cowpea genotypes are given in Table 3.3.

Table 3.2. Characters of sorghum genotypes

Particulars	Co 25	Co 22
Parentage	3-way cross derivative between (IS 4283x6997) x CS 3541	Composite (2077 A, 2219 A, 3660 A, IS 3541)
Duration (days)	115-120	90-100
Days to 50% bloom	65-70	55-60
Plant height (cm)	170-190	100-120
Number of leaves	7-9	5-7
Grain yield (kg ha ⁻¹)	1600-1900	1400-2000
Straw yield (q ha ⁻¹)	80-100	60-80

Table 3.3. Characters of cowpea genotypes

Particulars	Co 1	Co 4	CoVu 7
Plant height (cm)	70-75	40-45	30-35
Number of branches	5-7	4-5	3-4
Days to first flowering	45	40	35
Days to 50% flowering	55	45	40
Duration (days)	90-100	75-80	70-75
Growth habit	Tall branching climbing	Medium tall bushy spreading	Short, less branching erect
Pod length (cm)	15-20	20-25	20-25
Seeds per pod	12-14	14-15	15
100 grain weight (g)	7.5	12.5	10.8
Seed yield (g/plant)	20-25	25-30	20-25

3.2. Methods

3.2.1. Experimental design

The experiment during 1983-84 was laid out in a Factorial Randomised Blocks Design with three replications. In 1984-85 and 1985-86, a split plot design was adopted with three replications. The layout plans are shown in Fig 3.1 and 3.2.

3.2.2. Treatments

1983-84

The treatments included combinations of eleven cropping systems and two land management practices for moisture conservation as detailed below.

1. Sorghum Co 25 sole crop in flat bed	S ₁ M ₁
2. Sorghum Co 25 sole crop in bed furrow	S ₁ M ₂
3. Sorghum Co 22 sole crop in flat bed	S ₂ M ₁
4. Sorghum Co 22 sole crop in bed furrow	S ₂ M ₂
5. Cowpea Co 1 sole crop in flat bed	S ₃ M ₁
6. Cowpea Co 1 sole crop in bed furrow	S ₃ M ₂
7. Cowpea Co 3 sole crop in flat bed	S ₄ M ₁
8. Cowpea Co 4 sole crop in bed furrow	S ₄ M ₂
9. Cowpea CoVu 7 sole crop in flat bed	S ₅ M ₁
10. Cowpea CoVu 7 sole crop in bed furrow	S ₅ M ₂
11. Sorghum Co 25 + Cowpea Co 1 in flat bed	S ₆ M ₁
12. Sorghum Co 25 + Cowpea Co 1 in bed furrow	S ₆ M ₂
13. Sorghum Co 25 + Cowpea Co 4 in flat bed	S ₇ M ₁
14. Sorghum Co 25 + Cowpea 4 in bed furrow	S ₇ M ₂
15. Sorghum Co 25 + Cowpea CoVu 7 in flat bed	S ₈ M ₁
16. Sorghum Co 25 + Cowpea CoVu 7 in bed furrow	S ₈ M ₂
17. Sorghum Co 22 + Cowpea Co 1 in flat bed	S ₉ M ₁
18. Sorghum Co 22 + Cowpea Co 1 in bed furrow	S ₉ M ₂
19. Sorghum Co 22 + Cowpea Co 4 in flat bed	S ₁₀ M ₁

4)
4¹
4²

- | | |
|---|--------------------------------|
| 20. Sorghum Co 22 + Cowpea Co 4 in bed furrow | S ₁₀ M ₂ |
| 21. Sorghum Co 22 + Cowpea CoVu 7 in flat bed | S ₁₁ M ₁ |
| 22. Sorghum Co 22 + Cowpea CoVu 7 in bed furrow | S ₁₁ M ₂ |

1984-85 and 1985-86

The treatments included six cropping systems, two land management practices and three nitrogen levels. Combinations of cropping systems and land management practices were allotted to the main plots and nitrogen levels in the sub plots.

Main plots - cropping systems and land management (12)

- | | |
|---|-------------------------------|
| 1. Sorghum Co 25 sole crop in flat bed | S ₁ M ₁ |
| 2. Sorghum Co 25 sole crop in bed furrow | S ₁ M ₂ |
| 3. Sorghum Co 22 sole crop in flat bed | S ₂ M ₁ |
| 4. Sorghum Co 22 sole crop in bed furrow | S ₂ M ₂ |
| 5. Sorghum Co 25 + Cowpea Co 1 in flat bed | S ₃ M ₁ |
| 6. Sorghum Co 25 + Cowpea Co 1 in bed furrow | S ₃ M ₂ |
| 7. Sorghum Co 25 + Cowpea Co 4 in flat bed | S ₄ M ₁ |
| 8. Sorghum Co 25 + Cowpea Co 4 in bed furrow | S ₄ M ₂ |
| 9. Sorghum Co 22 + Cowpea Co 1 in flat bed | S ₅ M ₁ |
| 10. Sorghum Co 22 + Cowpea Co 1 in bed furrow | S ₅ M ₂ |
| 11. Sorghum Co 22 + Cowpea Co 4 in flat bed | S ₆ M ₁ |
| 12. Sorghum Co 22 + Cowpea Co 4 in bed furrow | S ₆ M ₂ |

Sub plot - Nitrogen levels (3)

- | | |
|-----------------------------|----------------|
| 1. No nitrogen | N ₁ |
| 2. 20 kg N ha ⁻¹ | N ₂ |
| 3. 40 kg N ha ⁻¹ | N ₃ |

FIG. 3-1 LAYOUT - 1983-84

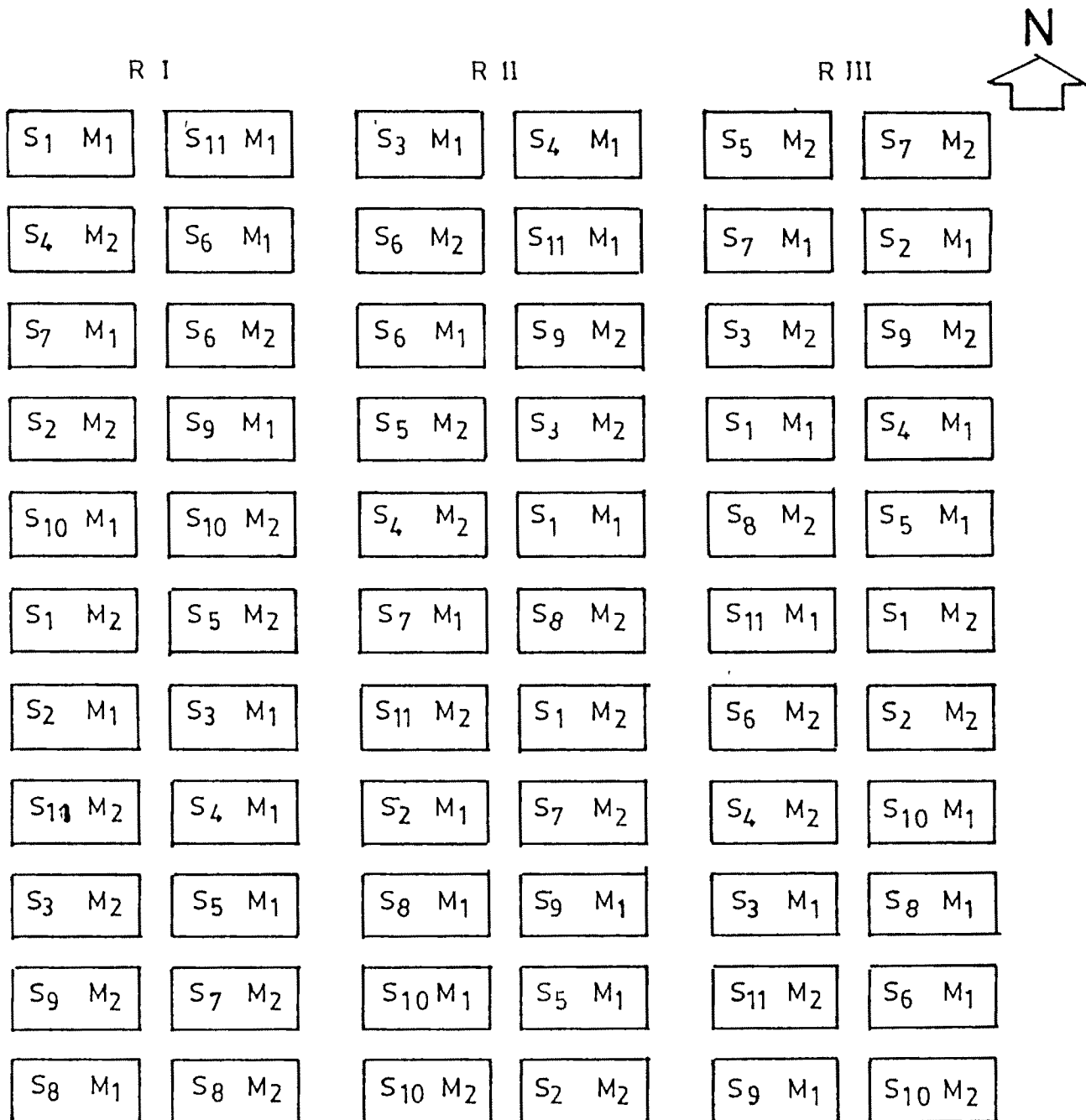
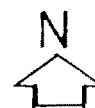


FIG. 3-2 LAYOUT-1984-85, 1985-86

43



40

S ₂ M ₁ N ₁	S ₂ M ₁ N ₃	S ₂ M ₁ N ₂
S ₅ M ₁ N ₂	S ₅ M ₁ N ₃	S ₅ M ₁ N ₁
S ₁ M ₁ N ₁	S ₁ M ₁ N ₂	S ₁ M ₁ N ₃
S ₆ M ₂ N ₂	S ₆ M ₂ N ₁	S ₆ M ₂ N ₃
S ₃ M ₁ N ₁	S ₃ M ₁ N ₃	S ₃ M ₁ N ₂
S ₂ M ₂ N ₁	S ₂ M ₂ N ₂	S ₂ M ₂ N ₃

S ₄ M ₁ N ₁	S ₄ M ₁ N ₃	S ₄ M ₁ N ₂
S ₄ M ₂ N ₂	S ₄ M ₂ N ₃	S ₄ M ₂ N ₁
S ₃ M ₂ N ₁	S ₃ M ₂ N ₂	S ₃ M ₂ N ₃
S ₅ M ₂ N ₂	S ₅ M ₂ N ₃	S ₅ M ₂ N ₁
S ₁ M ₂ N ₁	S ₁ M ₂ N ₃	S ₁ M ₂ N ₂
S ₆ M ₂ N ₃	S ₆ M ₂ N ₁	S ₆ M ₂ N ₂

R I

S ₁ M ₂ N ₁	S ₁ M ₂ N ₂	S ₁ M ₂ N ₃
S ₄ M ₁ N ₃	S ₄ M ₁ N ₁	S ₄ M ₁ N ₂
S ₆ M ₂ N ₂	S ₆ M ₂ N ₃	S ₆ M ₂ N ₁
S ₂ M ₁ N ₁	S ₂ M ₁ N ₃	S ₂ M ₁ N ₂
S ₄ M ₂ N ₂	S ₄ M ₂ N ₁	S ₄ M ₂ N ₃
S ₅ M ₁ N ₃	S ₅ M ₁ N ₂	S ₅ M ₁ N ₁

S ₂ M ₂ N ₁	S ₂ M ₂ N ₃	S ₂ M ₂ N ₂
S ₅ M ₂ N ₂	S ₅ M ₂ N ₁	S ₅ M ₂ N ₃
S ₆ M ₁ N ₁	S ₆ M ₁ N ₃	S ₆ M ₁ N ₂
S ₃ M ₁ N ₂	S ₃ M ₁ N ₁	S ₃ M ₁ N ₃
S ₁ M ₁ N ₁	S ₁ M ₁ N ₃	S ₁ M ₁ N ₂
S ₃ M ₂ N ₂	S ₃ M ₂ N ₁	S ₃ M ₂ N ₃

R II

S ₆ M ₁ N ₁	S ₆ M ₁ N ₂	S ₆ M ₁ N ₃
S ₂ M ₂ N ₂	S ₂ M ₂ N ₃	S ₂ M ₂ N ₁
S ₅ M ₁ N ₂	S ₅ M ₁ N ₁	S ₅ M ₁ N ₃
S ₄ M ₂ N ₁	S ₄ M ₂ N ₃	S ₄ M ₂ N ₂
S ₃ M ₁ N ₂	S ₃ M ₁ N ₁	S ₃ M ₁ N ₃
S ₅ M ₂ N ₁	S ₅ M ₂ N ₃	S ₅ M ₂ N ₂

S ₁ M ₁ N ₁	S ₁ M ₁ N ₃	S ₁ M ₁ N ₂
S ₆ M ₂ N ₂	S ₆ M ₂ N ₁	S ₆ M ₂ N ₃
S ₂ M ₁ N ₃	S ₂ M ₁ N ₂	S ₂ M ₁ N ₁
S ₁ M ₂ N ₁	S ₁ M ₂ N ₃	S ₁ M ₂ N ₂
S ₃ M ₂ N ₂	S ₃ M ₂ N ₃	S ₃ M ₂ N ₁
S ₄ M ₁ N ₁	S ₄ M ₁ N ₂	S ₄ M ₁ N ₃

R III

Plot size

	Gross	Net
1983-84	8.1 x 4.2 m	6.3 x 3.6 m
1984-85	7.2 x 3.6 m	5.4 x 3.0 m
1985-86	7.2 x 3.6 m	5.4 x 3.0 m

3.2.4. Cultural practices**a) Field preparation**

The experimental field was ploughed once with tractor drawn disc plough and then worked with tractor drawn cultivator. The field was marked into plots of the required dimension. For flat bed sowing, the sowing was done in the ploughed field as such. For bed furrow sowing, furrows were formed with a wooden plough at 60 cm interval to form beds of 60 cm width alternating with furrows of 30 cm width and 15 cm depth.

b) Seeds and sowing

Seeds of sorghum Co 25, sorghum Co 22, cowpea Co 1, Co 4 and CoVu 7 were obtained from the School of Genetics, Tamil Nadu Agricultural University, Coimbatore. The seed rates adopted were 10 kg ha⁻¹ for sorghum in sole as well as intercropping, 15 kg ha⁻¹ for sole cowpea and 5 kg ha⁻¹ for intercropped cowpea. Cowpea seeds were inoculated with rhizobial culture before sowing. Sowing was done by hand dibbling.

For sowing in flat beds, sorghum was sown in paired rows of 60 + 30 cm with a spacing of 15 cm in the line. For sowing in bed furrow, two sorghum rows were sown near the edges of the 60 cm wide bed with 15 cm spacing between plants. Sole crop of cowpea was sown with a spacing of 30 x 10 cm in flat beds as well as bed furrows. In intercropping systems one row of cowpea was sown in the middle of the interspace between the two sorghum rows with a spacing of 10 cm between plants in the line. The sowing methods are shown in Fig. 3.3. The populations of sorghum and cowpea in sole cropping and intercropping are given below.

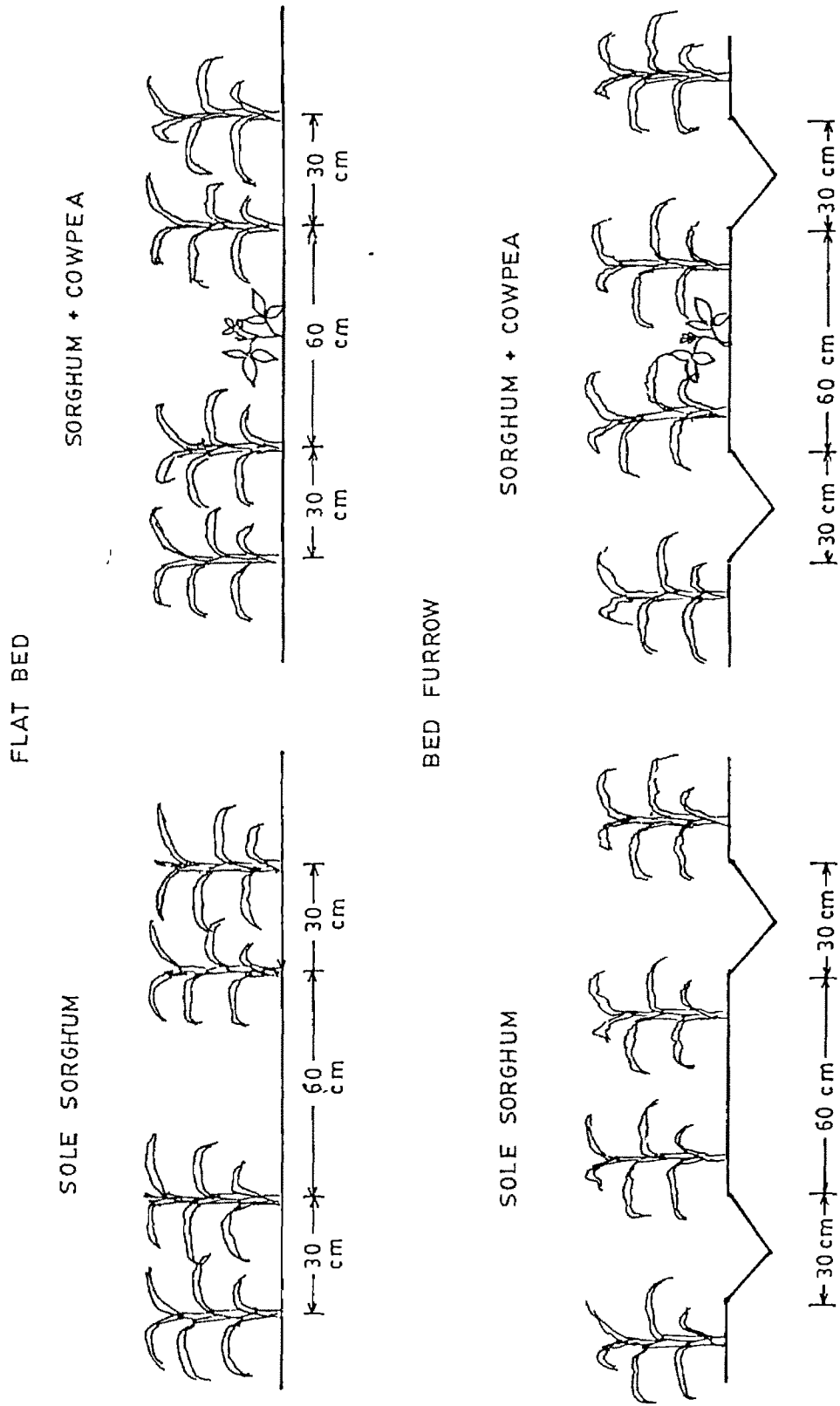
	Population per ha (10 ³)	
	Sole cropping	Intercropping
Sorghum	148	148
Cowpea	333	111

During 1984-85 and 1985-86, sole crops of the two cowpea genotypes Co 1 and Co 4 were raised in 80 m² plots adjacent to the experimental layout for the purpose of yield estimation for calculation of land equivalent ratio of intercropping systems as suggested by Mead and Stern (1981).

c) Fertilizer application

During 1983-84, fertilizer was applied at 40 kg N and 20 kg P₂O₅ per ha for sorghum in sole cropping and intercropping

FIG.3-3 SOWING IN FLAT BED AND BED FURROW



217/47

and at 10 kg N and 20 kg P_2O_5 per ha for sole cowpea. Superphosphate to supply the required P_2O_5 was applied basally before sowing. For sole cowpea, nitrogen as urea was also applied basally at sowing. For sorghum, 20 kg N was applied basally and the remaining 20 kg N topdressed at 20 days after sowing (DS).

In 1984-85 and 1985-86, superphosphate to supply 20kg P_2O_5 per ha was applied basally at sowing. Nitrogen was applied as per treatments. In N_{20} plots, 20 kg N ha^{-1} as urea was applied basally at sowing, In N_{40} plots, 20 kg N ha^{-1} was applied basally and the remaining 20 kg N ha^{-1} was topdressed at 20 DS and 30 DS in the second and third year respectively.

d) After cultivation

At 20 DS, one hand hoeing and weeding was given. Dusting BHC 10% at 25 kg ha^{-1} was done at milky stage against earhead bug in sorghum.

e) Harvest

Picking of pods in cowpea was done twice at 5-7 days interval depending on the duration of the variety.

After final picking, cowpea plants were cut at ground level, leaving the roots intact. In sorghum, at the maturity period corresponding to each genotype earheads were harvested first

Table 3.4. Dates of sowing and harvest of sorghum and cowpea genotypes

Crop and genotype	1983-84		1984-85		1985-86	
	D.S.	D.H.	D.S.	D.H.	D.S.	D.H.
Sorghum Co 25	19.10.83	15.02.84	21.09.84	23.01.85	28.09.85	21.01.86
Sorghum Co 22	19.10.83	29.01.84	21.09.84	03.01.85	28.09.85	07.01.86
Cowpea Co 1	19.10.83	21.01.84	21.09.84	25.12.84	28.09.85	30.12.85
Cowpea Co 4	19.10.83	11.01.84	21.09.84	10.12.84	28.09.85	13.12.85
Cowpea CoVu 7	19.10.83	04.01.84	-	-	-	-

44

D.S. - Date of sowing.

D.H. - Date of harvest

and then the stalks were cut in the net plot area after excluding border rows and sampling rows on either side. The dates of sowing and harvest of the genotypes of sorghum and cowpea in the three years are shown in Table 3.4.

3.3. Biometric observations

3.3.1. Sorghum

3.3.1.1. Plant height

Height of sorghum at harvest was measured from the lowest leaf axile to the tip of the panicle in 10 plants in each plot and expressed in cm.

3.3.1.2. Leaves per plant

Number of leaves per plant was counted at 75 DS in 10 plants per plot and the mean value was calculated.

3.3.1.3. Leaf Area Index (LAI)

The length and width (at the broadest part of lamina) of the fourth leaf from top at 75 DS were measured in ten plants per plot. Leaf Area Index was computed as suggested by Stickler *et al.* (1961).

$$\text{LAI} = \frac{l \times b \times 0.747 \times n}{S}$$

Where,

LAI = Leaf Area Index

l = Length of 4th leaf from top (cm)

b = Width of 4th leaf from top (cm)

n = Number of leaves per plant

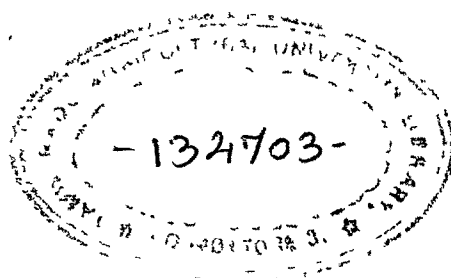
S = Space occupied per plant (cm²)

3.3.1.4. Dry matter production (DMP)

Five plants per plot were collected from sample rows. The plant samples were air dried and then oven dried at 70°C and dry weight recorded. During 1983-84, DMP of sorghum was estimated at 30 DS, 75 DS and at harvest. During 1984-85 and 1985-86, DMP was estimated at harvest. Dry matter production was expressed as q ha⁻¹. In 1985-86, dry matter weight of stems, leaves and ears were recorded separately for the sample plants for calculating the per cent distribution of dry matter between plant parts.

3.3.1.5. Earhead length

Length of earhead from base to tip was measured in 10 earheads per plot and the mean value expressed in cm.



3.3.1.6. Grain weight per earhead

Ten earheads from each plot were collected, threshed separately and the grain weight per earhead was recorded in grams.

3.3.1.7. Grain yield

Earheads collected from net plot^s were dried, threshed and grain yield after drying was recorded in each plot, computed to 14% moisture content and expressed as q ha⁻¹.

3.3.1.8. Straw yield

Stalks cut from net plot area were air dried in open for 10 days and the dry weight of straw per plot was expressed as q ha⁻¹.

3.3.1.9. Harvest Index (HI)

Harvest Index was worked out as below:

$$HI = \frac{\text{Grain yield}}{\text{Total DMP at harvest}}$$

3.3.2. Cowpea

3.3.2.1. Plant height

Height of 10 plants of cowpea from ground level to the tip of the terminal shoot was measured at 50 DS in each plot to calculate the mean plant height in cm during 1983-84.

3.3.2.2. Leaf area and Leaf weight

During 1985-86 all the leaves per plant in 3 plants per plot in one replication were collected and leaf area per plant was estimated using a leaf area meter. The green weight of leaves per plant was estimated immediately after collection.

3.3.2.3. Specific leaf area

The ratio between leaf area and leaf weight per plant was computed and expressed as specific leaf area.

3.3.2.4. Dry matter production

From the sample rows, five plants were cut at ground level at the first picking of pods, air dried and then oven dried at 70°C and the dry weight was recorded. The DMP at harvest was expressed as $q\ ha^{-1}$. During 1985-86, the dry weight of stems, leaves and pods were estimated separately for calculating the per cent distribution of dry matter between plant parts.

3.3.2.5. Pods per plant

Pods per plant in 10 plants per plot were counted in each picking and total pods produced per plant was recorded.

3.3.2.6. Pod length

Length of 10 pods from each plot was measured and mean length of pod expressed in cm.

3.3.2.7. Grains per pod

Grains in each of 10 pods collected from each plot were counted and the mean number of grains per pod was calculated.

3.3.2.8. Grain test weight

Two samples of 100 grains each from each plot were counted and from the weight of grains, the grain test weight of 100 grains was expressed in grams.

3.3.2.9. Grain yield

The weight of cleaned and dried grains received after threshing of pods collected from each net plot was recorded and expressed as grain yield in kg ha^{-1} .

3.3.2.10. Haulms yield

After final picking of pods, the plants were cut at ground level allowed to dry in the open for 7 days and the weight of dried haulms per plot was recorded and expressed in q ha^{-1} .

3.3.2.11. Harvest Index

Harvest index was computed as the ratio between grain yield and total DMP at harvest.

3.3.3. Cropping systems

3.3.3.1. Total DMP of cropping system

For sole crops of sorghum and cowpea, total DMP of the system at harvest was the same as in sole cropping. For intercropping systems, the sum of DMP of sorghum and DMP of cowpea at harvest was taken as total DMP of the system and expressed in $q\ ha^{-1}$.

3.3.3.2. Weed dry weight

During 1983-84, weeds were removed from two quadrats of $0.50\ m^2$ in each plot at 40 DS and the dry weight of weeds was recorded and expressed as $g\ m^{-2}$.

3.4. Soil analysis

3.4.1. Soil moisture

Soil samples were drawn with a screw auger and soil moisture per cent was estimated by gravimetric method at sowing, 60/70 DS, 80 DS, at sorghum Co 22 harvest and at sorghum Co 25 harvest. Soil moisture was estimated in 0-60 cm depth at sowing and at sorghum harvest and in 0-30 cm depth at 60/70 DS and 80 DS.

3.4.2. Soil moisture balance

The soil moisture balance during the crop growth was computed from the soil moisture at sowing, rainfall received on each rainy day and the cumulative crop evapotranspiration between two successive rainy days.

3.4.3. Evapotranspiration

Reference crop evapotranspiration (ET_0) was computed from weekly data on maximum and minimum temperature, mean minimum relative humidity, sunshine hours and estimated wind velocity by the modified Blaney and Criddle method suggested by Doorenbos and Pruitt (1975).

$$ET_0 = C [p (0.46 t + 8)]$$

Where,

ET_0 = Reference crop evapotranspiration in mm day^{-1}

t = Mean temperature $^{\circ}\text{C}$

p = Mean daily percentage of total annual day time hours

C = Adjustment factor depending on mean minimum relative humidity, sunshine hours and wind estimate.

The crop evapotranspiration was estimated by using crop coefficient values for sorghum as suggested by Subramanian and Kulandaivelu (1986).

$$ET_{\text{crop}} = ET_0 \times K_c$$

Where,

ET_{crop} = Crop evapotranspiration

ET_0 = Reference crop evapotranspiration

K_c = Crop coefficient

The crop coefficients used in the study are as below

Cropping system	Sorghum growth stage	Kc
Sorghum Co 25 based cropping systems	0 - 20 DS	0.35
	21 - 55 DS	0.80
	56 - 80 DS	1.00
	81 - 120 DS	0.50
Sorghum Co 22 based cropping systems	0 - 20 DS	0.35
	21 - 50 DS	0.80
	51 - 75 DS	1.00
	76 - 105 DS	0.50

Effective rainfall was calculated by subtracting the probable run-off from total rainfall. Run-off was assumed to be the difference between soil moisture before rainfall plus rainfall minus maximum available water holding capacity in 60 cm depth.

3.4.4. Chemical analysis of soil

Soil samples prior to sowing were analysed for available N, P and K as per recommended methods. Organic Carbon, pH and EC were also estimated.

Available nutrient	Method	Suggested by
N	Alkaline permanganate	Subbiah and Asija (1956)
P	Olsen's method	Olsen et al. (1954)
K	Ammonium acetate extract-flame photometry	Jackson (1973)
Organic carbon		Jackson (1973)
pH	1 : 2 soil-water-pH meter	-
EC	1 : 2 soil water-solubridge	-

3.5 Plant analysis

3.5.1. Nitrogen uptake

Grain and stalk samples of sorghum and cowpea from each plot during the second and third year were used for analysis of nitrogen content by the MicroKjeldahl method suggested by Humphries (1956). From the values of nitrogen concentration and dry weight of grain and stalks/haulms, the uptake of nitrogen was computed and expressed in kg ha^{-1} . Total uptake of nitrogen by the intercropping system was computed as the sum of nitrogen uptake by the two component crops in intercropping.

3.5.2. Crude protein content of dry fodder

From the nitrogen content of the stalks and haulms of sorghum and cowpea, respectively, the crude protein content of dry fodder was estimated, using the factor of 6.25.

3.6. Cropping system evaluation

3.6.1. Expected yield in intercropping

Expected grain yield of sorghum and cowpea in intercropping was estimated from respective sole crop yield and population in sole and intercropping systems.

$$EY_{ab} = Y_{aa} \times \frac{P_{ab}}{P_{aa}}$$

Where,

EY_{ab} = Expected yield of species 'a' intercropped with species 'b'

a, b = Component crops

Y_{aa} = Yield of 'a' as sole crop

P_{aa} = Population of 'a' in sole crop

P_{ab} = Population of 'a' in intercropping

3.6.2. Aggressivity

Aggressivity values for the component crops in intercropping were worked out by the following formula suggested by Mc Gilchrist (1965).

$$A_{ab} = \frac{Y_{ab}}{EY_{ab}} - \frac{Y_{ba}}{EY_{ba}}$$

Where,

A_{ab} = Aggressivity of species 'a'

a, b = Component crop species

Y_{ab} = Yield of 'a' in intercropping with 'b'

Y_{ba} = Yield of 'b' in intercropping with 'a'

EY_{ab} = Expected yield of 'a' in intercropping

EY_{ba} = Expected yield of 'b' in intercropping

3.6.3. Relative crowding coefficient

Relative crowding coefficients for the component crops were worked out as suggested by De wit (quoted by Willey and Rao, 1980).

$$K_{ab} = \frac{Y_{ab} \times Z_{ba}}{(y_{aa} - Y_{ab}) \times Z_{ab}}$$

Where,

K_{ab} = Relative crowding coefficient of 'a' intercropped with 'b'

Y_{aa} = Yield of 'a' in sole cropping

Y_{ab} = Yield of 'a' in intercropping

Z_{ab} = Proportion of intercropped area initially allotted to 'a'

Z_{ba} = Proportion of intercropped area initially allotted to 'b'

3.6.4. Competition Ratio

Competition Ratio for the component crops was worked out as suggested by Willey and Rao (1980).

$$CR_{ab} = \frac{LER_a}{LER_b} \times \frac{Z_{ba}}{Z_{ab}}$$

Where,

CR_{ab} = Competition ratio of 'a' in intercropping with 'b'

LER_a = Land equivalent ratio of 'a'

LER_b = Land equivalent ratio of 'b'

3.6.5. Land equivalent ratio

Land equivalent ratio of the component crops was worked out by the formula:

$$\text{LER}_a = \frac{Y_{ab}}{Y_{aa}} \qquad \text{LER}_b = \frac{Y_{ba}}{Y_{bb}}$$

Where,

LER_a , LER_b = Land equivalent ratio of component crops
 Y_{aa} , Y_{bb} = Yield of 'a' and 'b' in sole cropping respectively
 Y_{ab} , Y_{ba} = Yield of 'a' and 'b' in intercropping respectively

Land equivalent ratio of the intercropping systems was computed as the sum of the land equivalent ratio of the component crops.

$$\text{LER} = \text{LER}_a + \text{LER}_b$$

3.7. Economic analysis

The cost of cultivation, gross return, net economic return and the cost-benefit ratio of the treatments were worked out based on the prevailing market prices for inputs and produce and as per wages paid to labourers at the Central Farm, Tamil Nadu Agricultural University, Coimbatore.

3.8. Statistical analysis

The data were subjected to statistical analysis by analysis of variance method as suggested by Panse and Sukatme (1985). Correlation coefficients (r) and simple regression coefficient (b) were calculated as per the approved procedure (Gomez and Gomez, 1981).

RESULTS

4. RESULTS

With the objective of evaluating the advantages of rainfed sorghum - cowpea intercropping, field experiments were conducted for three seasons in 1983-84, 1984-85 and 1985-86 at Tamil Nadu Agricultural University, Coimbatore. The main objectives of the study were to assess the influence of genotypes of the component crops, land management practices for moisture conservation and nitrogen application on the growth and yield of the component crops, the monetary advantages of sorghum - cowpea intercropping and the competitive ability of the component crop genotypes in intercropping. The results obtained in the three year study are presented in this chapter.

4.1. Sorghum growth and yield

4.1.1. Plant height (Table 4.1)

The height of sorghum plants at harvest differed only marginally between sole cropping and intercropping with all the cowpea genotypes. Plants of sorghum Co 25 in sole as well as intercropping systems were taller than those of sorghum Co 22.

In all the three years, the height of sorghum plants remained unaffected due to a change in land management practice from flat bed sowing to bed furrow sowing. There was little influence on sorghum height due to the interaction effect between sole and intercropping systems with land management practices.

Table 4.1. Sorghum height at harvest in sole and intercropping systems under land management and nitrogen levels

		Sorghum height at harvest (cm)								
		83 - 84		84 - 85		85 - 86				
		Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25	Sole	159.6	161.0	160.3	153.7	163.2	158.4	171.3	178.1	174.7
Co 22	Sole	91.6	90.3	90.9	95.2	99.2	97.2	104.4	111.1	107.8
Co 25 + Co 1		157.2	160.9	159.0	149.3	154.5	151.9	171.9	179.7	175.8
Co 25 + Co 4		153.0	163.8	158.4	152.9	152.1	152.5	164.2	172.5	168.7
Co 25 + CoVu 7		152.7	156.5	154.6	-	-	-	-	-	-
Co 22 + Co 1		86.3	85.4	85.9	88.7	90.9	89.8	105.8	109.1	107.4
Co 22 + Co 4		89.2	86.0	87.6	93.1	93.9	93.5	105.0	106.8	105.9
Co 22 + CoVu 7		81.7	89.1	85.4	-	-	-	-	-	-
		121.4	124.1		122.1	125.6		137.1	142.9	
N ₀		-	-	-	-	-	120.2	-	-	136.2
N ₂₀		-	-	-	-	-	123.8	-	-	140.1
N ₄₀		-	-	-	-	-	127.6	-	-	143.7
S		SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD
M		4.22	4.22	8.61	4.12	4.12	8.55	8.05	8.05	16.77
S x M		2.11	2.11	NS	2.38	2.38	NS	4.67	4.67	NS
N		5.97	5.97	NS	5.83	5.83	NS	11.44	11.44	NS
		-	-	-	1.52	1.52	3.06	1.35	1.35	2.72

62
6
13

Sorghum height was increased by the application of nitrogen, and 40 kg N had greater effect than 20 kg N. The interaction between cropping systems and N application and between land management and N application showed negligible effect on sorghum height.

4.1.2. Leaves per plant at flowering (Table 4.2)

The only difference noticed in the number of leaves per plant at flowering was between the two sorghum genotypes. Sorghum Co 25 produced 1-2 leaves more than sorghum Co 22, in all the three years. Leaf number per plant within each sorghum genotype remained unchanged between sole sorghum and sorghum in intercropping with any of the cowpea genotypes.

Production of leaves by sorghum was least affected by the land management practices or their interaction with the cropping systems.

The number of leaves per plant registered an increase due to nitrogen application in the third year of study, with the effect being on par between 20 and 40 kg levels. The interaction between cropping systems and N application and that between land management and N application caused little change in leaves produced by sorghum.

Table 4.2. Leaves per plant in sorghum at flowering in sole and intercropping systems under land management and nitrogen levels

	No. of leaves per plant in sorghum at flowering											
	83 - 84			84 - 85			85 - 86					
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 Sole	6.9	7.1	7.0	7.9	7.0	7.5	8.0	8.1	7.5	8.0	8.0	8.0
Co 22 Sole	6.5	6.2	6.4	5.9	6.2	6.1	6.8	6.8	6.1	6.8	6.8	6.8
Co 25 + Co 1	7.1	7.2	7.2	6.8	7.3	7.1	8.0	7.9	7.1	8.0	8.0	8.0
Co 25 + Co 4	6.8	7.6	7.2	7.2	7.1	7.1	7.8	7.8	7.1	7.8	7.8	7.8
Co 25 + CoVu 7	7.1	7.0	7.0	-	-	-	-	-	-	-	-	-
Co 22 + Co 1	6.2	5.5	5.9	6.0	5.7	5.9	6.7	6.8	5.9	6.8	6.8	6.8
Co 22 + Co 4	6.3	6.1	6.2	5.7	5.6	5.6	6.7	6.8	5.6	6.8	6.7	6.7
Co 22 + CoVu 7	6.1	6.7	6.4	-	-	-	-	-	-	-	-	-
	6.6	6.7	6.6	6.6	6.5	6.6	7.3	7.4	6.6	7.3	7.4	7.4
N ₀	-	-	-	-	-	-	-	-	6.6	-	-	7.2
N ₂₀	-	-	-	-	-	-	-	-	6.5	-	-	7.4
N ₄₀	-	-	-	-	-	-	-	-	6.4	-	-	7.4
	SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD
S	0.27	0.27	0.55	0.31	0.31	0.63	0.12	0.12	0.24	0.12	0.12	0.24
M	0.13	0.13	NS	0.18	0.18	NS	0.07	0.07	NS	0.07	0.07	NS
S x M	0.38	0.38	NS	0.44	0.44	NS	0.16	0.16	NS	0.16	0.16	NS
N				0.14	0.14	NS	0.07	0.07	NS	0.07	0.07	0.12

64

NS

4.1.3. Leaf area index (Table 4.3)

In all the three years, sorghum Co 25 recorded larger leaf area index (LAI) at flowering over sorghum Co 22. Within each sorghum genotype, LAI at flowering did not vary much between sole sorghum and sorghum intercropped with cowpea. The only exception was a reduction in the LAI of sorghum Co 22 intercropped with cowpea Co 1 in the first year.

The difference in LAI of sorghum between flat bed sowing and bed furrow sowing was insignificant in sole sorghum as well as intercropped sorghum.

There was a progressive increase in the LAI of sorghum with every increment of N applied and this beneficial effect was seen in both sole cropping and intercropping under both the land management practices.

4.1.4. Dry matter production

Dry matter per plant at various stages of sorghum growth in the first year showed only marginal differences between sole cropping and intercropping for each sorghum genotype (Table 4.4). Sorghum Co 25, however, produced, higher dry matter per plant than sorghum Co 22 at all the growth stages from 30 DS to harvest, in both sole cropping and intercropping with cowpea.

Table 4.3. Leaf area index of sorghum at flowering in sole and intercropping systems under land management and nitrogen levels

	83 - 84				84 - 85				85 - 86			
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 Sole	4.44	3.74	4.09	4.42	4.29	4.35	4.39	4.30	4.34			
Co 22 Sole	2.86	2.67	2.76	2.97	2.95	2.96	3.18	3.15	3.17			
Co 25 + Co 1	3.42	3.96	3.69	4.11	4.31	4.21	4.20	4.28	4.24			
Co 25 + Co 4	4.04	4.15	4.09	4.31	4.32	4.32	4.25	4.24	4.25			
Co 25 + CoVu 7	3.57	3.93	3.75	-	-	-	-	-	-			
Co 22 + Co 1	2.41	2.05	2.23	3.01	3.12	3.07	3.21	3.31	3.26			
Co 22 + Co 4	2.35	2.39	2.37	2.73	2.85	2.79	2.95	3.07	3.01			
Co 22 + CoVu 7	2.46	2.65	2.55	-	-	-	-	-	-			
	3.19	3.19		3.59	3.64		3.70	3.72				
N ₀			-			3.39			3.48			
N ₂₀			-			3.61			3.70			
N ₄₀			-			3.85			3.95			
S	SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD
M	0.22	0.22	0.46	0.18	0.18	0.38	0.15	0.15	0.32	0.15	0.15	0.32
S x M	0.11	0.11	NS	0.11	0.11	NS	0.09	0.09	NS	0.09	0.09	NS
N	0.32	0.32	NS	0.26	0.26	NS	0.22	0.22	NS	0.22	0.22	NS
				0.11	0.11	0.22	0.09	0.09	0.18	0.09	0.09	0.18

66
66

Table 4.4. Dry matter production per plant in sorghum under sole and intercropping systems and land management (1983-84)

	Sorghum dry matter per plant (g)									
	30 DS			75 DS			Harvest			
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Mean
Co 25 Sole	5.9	5.2	5.5	31.7	27.2	29.5	38.6	40.9	39.7	
Co 22 Sole	4.4	4.4	4.4	25.8	25.0	25.4	29.7	28.6	29.1	
Co 25 + Co 1	5.5	5.3	5.4	28.7	28.6	28.7	34.5	37.5	36.0	
Co 25 + Co 4	5.5	5.7	5.6	27.3	31.2	29.3	39.1	38.7	38.9	
Co 25 + CoVu 7	5.1	5.4	5.3	29.7	29.4	29.6	36.6	36.1	36.3	
Co 22 + Co 1	4.0	4.0	4.0	25.2	24.3	24.7	26.2	29.3	27.7	
Co 22 + Co 4	4.2	3.9	4.1	25.7	25.9	25.8	30.6	30.2	30.4	
Co 22 + CoVu 7	4.0	3.9	3.9	25.0	25.4	25.2	28.4	28.4	28.4	
	4.8	4.7		27.4	27.1		33.0	33.7		

	SE _d	CD	SE _d	CD	SE _d	CD
S	0.34	0.69	1.43	2.92	2.31	4.72
M	0.17	NS	0.71	NS	1.15	NS
S x M	0.47	NS	2.02	NS	3.27	NS

67
67

Sorghum DMP per ha at harvest was higher by 8-18 q ha⁻¹ with sorghum Co 25 over sorghum Co 22 (Table 4.5). Within each sorghum genotype, the DMP at harvest was unaffected due to intercropping with any of the cowpea genotypes.

Sorghum DMP in sole cropping and in the different intercrop combinations showed only marginal differences between the two land management practices of flat bed sowing and bed furrow sowing.

Dry matter production of sorghum was positively influenced by the application of nitrogen, with 40 kg level proving to be more effective than 20 kg level. The positive effect of N in increasing the DMP of sorghum was seen in sole cropping as well as intercropping with the different cowpea genotypes. The interaction effect of N application with land management practices on sorghum DMP was not significant.

4.1.5. Earhead length (Table 4.6)

The length of sorghum earheads in sole cropping and in intercropping with cowpea genotypes was nearly similar. The difference in earlength between the two sorghum genotypes was less significant.

Longer earheads were produced under bed furrow sowing in the third year but no difference was seen between the two land

Table 4.5. Sorghum dry matter production at harvest in sole and intercropping under land management and nitrogen levels

		Sorghum DMP at harvest ($q\ ha^{-1}$)											
		83 - 84				84 - 85				85 - 86			
		Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25	Sole	57.1	60.5	58.8	57.7	60.0	57.8	57.8	58.9	58.3			
Co 22	Sole	43.9	42.3	43.1	48.5	50.5	49.5	41.8	43.3	42.5			
Co 25 + Co 1		51.1	55.5	53.3	56.6	56.1	56.4	55.1	55.9	55.5			
Co 25 + Co 4		57.9	57.3	57.6	54.9	55.9	55.4	55.2	56.4	55.8			
Co 25 + CoVu 7		54.2	53.3	53.7	-	-	-	-	-	-			
Co 22 + Co 1		38.7	43.4	41.0	47.3	48.1	47.7	39.7	40.1	39.9			
Co 22 + Co 4		45.3	44.7	45.0	48.0	46.6	47.3	40.2	41.1	40.7			
Co 22 + CoVu 7		42.0	42.0	42.0	-	-	-	-	-	-			
		48.8	49.9		52.2	52.5		48.3	49.3				
N ₀							46.6						43.5
N ₂₀							54.0						49.2
N ₄₀							56.4						53.6
S		SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD
M		3.42	3.42	6.98	1.86	1.86	3.86	1.64	1.64	3.41	1.64	1.64	3.41
S x M		1.71	1.71	NS	1.08	1.08	NS	0.95	0.95	NS	0.95	0.95	NS
N		4.83	4.83	NS	2.63	2.63	NS	2.32	2.32	NS	2.32	2.32	NS
		-	-	-	0.54	0.54	1.09	0.62	0.62	1.25	0.62	0.62	1.25

69

69

Table 4.6. Sorghum ear length in sole and intercropping systems under land management and nitrogen levels

		Sorghum earhead length (cm)									
		83 - 84			84 - 85			85 - 86			
		Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	
Co 25	Sole	24.4	23.6	24.0	22.7	23.1	22.9	21.2	22.9	22.1	22.1
Co 22	Sole	23.6	23.5	23.5	22.2	23.5	22.9	20.6	22.3	21.4	21.4
Co 25 + Co 1		22.9	22.1	22.5	22.4	22.0	22.2	21.5	22.8	22.1	22.1
Co 25 + Co 4		23.5	22.1	22.8	23.4	22.1	22.8	21.0	22.7	21.8	21.8
Co 25 + CoVu 7		23.1	22.1	22.6	-	-	-	-	-	-	-
Co 22 + Co 1		22.7	22.4	22.5	21.8	22.6	22.2	20.2	21.6	20.9	20.9
Co 22 + Co 4		22.9	22.3	22.6	22.7	22.2	22.4	20.6	22.3	21.4	21.4
Co 22 + CoVu 7		22.4	22.3	22.3	-	-	-	-	-	-	-
		23.2	22.6	22.6	22.6	22.6	22.6	20.8	22.4	20.8	20.8
	N ₀						21.7				20.8
	N ₂₀						22.6				21.6
	N ₄₀						23.4				22.5
			SF _d	CD		SE _d	CD		SE _d	CD	
S			1.34	NS		0.66	NS		0.51	NS	10
M			0.67	NS		0.38	NS		0.29	0.61	
S x M			1.89	NS		0.93	NS		0.72	NS	20
N			-	-		0.39	0.78		0.23	0.45	

management practices in the first and second year. Sorghum ear length was unaffected due to the interaction between cropping systems and land management.

An increase in sorghum earlength was caused by N application in both the years. Application of N at 40 kg resulted in longer earheads than at 20 kg N ha⁻¹. The effect of N on sorghum earlength in both sole sorghum and the different intercrop combinations was of the same magnitude.

4.1.6. Grain weight per ear (Table 4.7)

Grain weight per sorghum earhead, showed little difference between sole cropping and intercropping with the two cowpea genotypes. During 1984-85, grain weight per ear was higher in sorghum Co 25 over sorghum Co 22 but during 1985-86 both the sorghum genotypes recorded nearly similar grain weight per ear.

Higher grain weight per sorghum earhead was recorded under bed furrow sowing over flat bed sowing during 1984-85 only. In both the years, sorghum grain weight per ear was unaffected due to the interaction effect between the cropping systems and the land management practices.

Grain weight per ear in sorghum increased with the increment in N applied and this positive effect of N application on grain weight

Table 4.7. Sorghum grain weight per ear in sole and intercropping under land management and nitrogen levels

	Grain weight per ear (g)					
	1984 - 85			1985 - 86		
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 sole	7.3	7.7	7.5	5.7	5.6	5.7
Co 22 sole	6.4	6.8	6.6	6.0	5.8	5.9
Co 25 + Co 1	7.5	7.8	7.7	5.7	5.7	5.7
Co 25 + Co 4	7.3	7.5	7.4	5.5	5.7	5.6
Co 22 + Co 1	6.3	6.7	6.5	5.9	5.9	5.9
Co 22 + Co 4	6.2	6.6	6.4	5.8	6.0	5.9
	6.8	7.2		5.8	5.8	
N ₀			6.5			4.8
N ₂₀			7.0			5.9
N ₄₀			7.5			6.7
		SE _d	CD		SE _d	CD
S		0.17	0.35		0.19	NS
M		0.10	0.20		0.11	NS
S x M		0.24	NS		0.27	NS
N		0.08	0.16		0.07	0.15

per ear occurred in both sole sorghum and sorghum intercropped with cowpea. Interaction effect between land management and N application on sorghum grain weight per ear was absent.

4.1.7. Grain yield

In the first year, continuous rainfall during the period from 62-70 DS, adversely affected grain setting in both the sorghum genotypes, leading to complete chaffiness in Co 25 and mould infection in Co 22 earheads.

Sorghum grain yield differed between the two sorghum genotypes during 1984-85, with sorghum Co 25 recording higher grain yield over sorghum Co 22 (Table 4.8). During 1985-86, however, both the sorghum genotypes produced similar grain yield.

Grain yield within each sorghum genotype was unaffected due to intercropping with any of the two cowpea genotypes. The grain yield of sorghum Co 25 in intercropping systems ranged from 97 to 103 per cent of sole crop yield whereas that of sorghum Co 22 varied from 95 to 101 per cent of its sole crop yield in the two years.

There was an increase in sorghum grain yield (0.34 q ha^{-1}) under bed furrow sowing over flat bed sowing during 1984-85 but there was little difference in grain yield in 1985-86 due to the change

Table 4.8. Sorghum grain yield in sole and intercropping under land management and nitrogen levels

	Sorghum grain yield (q ha ⁻¹)					
	1984 - 85			1985 - 86		
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 sole	10.22	10.68	10.45	7.98	7.83	7.90
Co 22 sole	9.01	9.61	9.31	8.36	8.17	8.27
Co 25 + Co 1	10.64	11.00	10.82	7.78	7.84	7.81
Co 25 + Co 4	10.14	10.42	10.28	7.57	7.80	7.68
Co 22 + Co 1	9.02	9.41	9.22	8.24	8.25	8.25
Co 22 + Co 4	8.91	8.89	8.90	8.13	8.53	8.33
	9.66	10.00		8.01	8.07	
N ₀			8.99			6.58
N ₂₀			9.90			8.16
N ₄₀			10.61			9.37
		SE _d	CD		SE _d	CD
S		0.27	0.57		0.27	NS
M		0.16	0.33		0.15	NS
S x M		0.39	NS		0.38	NS
N		0.12	0.24		0.12	0.24

in land management practice. Grain yield of sorghum was less affected by the effect of the interaction between cropping systems and land management practices.

Significant increase in sorghum grain yield resulted from the application of nitrogen (Table 4.9) with 40 kg N being superior to 20 kg N level in both the years. The interaction effect of cropping systems and N application on sorghum grain yield was nonsignificant in both the years. At 0 N level, the grain yield of sorghum within each genotype, remained the same in sole cropping as well as intercropping with any of the cowpea genotypes. The positive influence of every increment in N level was recorded in sole sorghum as well as sorghum intercropped with the two cowpea genotypes.

Sorghum grain yield was less affected due to the interaction effect between land management practices and N application (Table 4.10).

4.1.8. Straw yield (Table 4.11)

Sorghum straw yield within each sorghum genotype was comparable between sole cropping and intercropping with all the cowpea genotypes. Sorghum Co 25 recorded higher straw yield over sorghum Co 22, in sole as well as intercropping.

Sorghum straw yield was least affected by variation in land management practices and its interaction with the cropping systems.

Table 4.9. Grain yield of sorghum (q ha^{-1}) in sole and intercropping under nitrogen levels

Cropping system	1984-85			1985-86		
	N_0	N_{20}	N_{40}	N_0	N_{20}	N_{40}
Co 25 sole	9.65	10.40	11.30	6.41	8.04	9.26
Co 22 sole	8.58	9.20	10.15	6.86	8.40	9.54
Co 25 + Co 1	9.90	10.92	11.65	6.31	7.92	9.20
Co 25 + Co 4	9.77	10.33	10.75	6.19	7.81	9.04
Co 22 + Co 1	8.05	9.48	10.12	6.83	8.36	9.54
Co 22 + Co 4	7.93	9.08	9.68	6.87	8.46	9.66
Mean	8.99	9.90	10.61	6.58	8.16	9.37
		SE_d	CD		SE_d	CD
N		0.12	0.24		0.12	0.24
S at N		0.37	NS		0.38	NS
N at S		0.30	NS		0.30	NS

Table 4.10. Grain yield of sorghum (q ha^{-1}) under land management and nitrogen levels

Land management (M)	1984-85			1985-86		
	N_0	N_{20}	N_{40}	N_0	N_{20}	N_{40}
Flat bed	8.78	9.71	10.49	6.47	8.15	9.40
Bed furrow	9.18	10.09	10.73	6.68	8.18	9.35
		SE_d	CD		SE_d	CD
M at N		0.21	NS		0.22	NS
N at M		0.17	NS		0.17	NS

Application of N increased the straw yield of sorghum. The interaction effect of cropping systems and N application on sorghum straw yield was not significant. In sole cropping as well as intercropping systems, there was a progressive increase in sorghum straw yield with addition of N at 20 and 40 kg levels. Sorghum straw yield remained unaffected due to the interaction between land management and N application.

4.1.9. Nitrogen uptake

Within each sorghum genotypes, N uptake did not differ between sole cropping and intercropping with any of the two cowpea genotypes (Table 4.12).

Sowing in bed furrow or flat bed caused little change in the uptake of N by sorghum. The interaction effect of cropping systems and land management practices did not lead to any variation in N uptake by sorghum.

Nitrogen uptake by sorghum in sole cropping as well as intercropping systems increased progressively with the addition of N, from 0 to 20 kg and from 20 to 40 kg ha⁻¹.

4.2. Cowpea growth and yield

4.2.1. Plant height (Table 4.13)

Plant height of cowpea recorded at 50 DS during the first year exhibited significant differences between genotypes in

Table 4.12. Nitrogen uptake by sorghum in sole and intercropping

	N uptake (kg ha ⁻¹)					
	1984 - 85			1985 - 86		
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 sole	58.6	59.6	59.1	57.7	59.4	58.6
Co 22 sole	51.5	53.2	52.4	46.1	45.8	46.0
Co 25 + Co 1	58.7	58.2	58.5	54.8	56.6	55.7
Co 25 + Co 4	57.0	57.2	57.1	56.6	54.9	55.8
Co 22 + Co 1	49.9	51.3	50.6	45.1	45.5	45.3
Co 22 + Co 4	50.2	50.2	50.2	45.9	45.1	45.5
	54.3	54.9		51.0	51.2	
N ₀			45.7			41.4
N ₂₀			56.8			52.6
N ₄₀			61.4			59.4
		SE _d	CD		SE _d	CD
S		1.37	2.85		2.29	4.75
M		0.79	NS		1.32	NS
S x M		1.94	NS		3.24	NS
N		0.51	1.02		0.75	1.52

sole cropping and intercropping systems. Plants of cowpea Co 1 recorded similar height in both sole cropping as well as intercropping with the two sorghum genotypes but were taller than plants of Co 4 as sole crop and plants of CoVu 7 in sole as well as intercropping. Plants of cowpea Co 4 were intermediate in height between Co 1 and CoVu 7 genotypes and its height was slightly increased in intercropping with sorghum Co 22. Cowpea CoVu 7 recorded the least height among all the three cowpea genotypes in sole as well as intercropping systems.

Plant height of cowpea genotypes was less affected by the land management practices and their interaction with cropping systems.

4.2.2. Dry matter production

Cowpea dry matter production per plant at harvest differed between sole cropping and intercropping during the first year (Table 4.13). As sole crop, all the three cowpea genotypes - Co 1, Co 4 and CoVu 7 - showed only marginal difference in DMP per plant. But as an intercrop, cowpea Co 4 and CoVu 7 recorded lesser DMP per plant with both the sorghum genotypes than their respective sole crops. In cowpea Co 1, reduction in DMP per plant due to intercropping was seen only with sorghum Co 25.

In intercropping systems, there was a considerable reduction in DMP per ha at harvest in all the cowpea genotypes as compared

Table 4.13. Cowpea height and DMP per plant in sole and intercropping under land management (1983-84)

	Plant height (cm)			DMP per plant at harvest (g)		
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 1 sole	47.1	47.1	47.1	3.9	3.5	3.7
Co 4 sole	34.9	38.7	36.8	4.3	3.6	4.0
CoVu 7 sole	32.7	29.7	31.2	3.9	3.6	3.7
Co 25 + Co 1	47.6	47.3	47.5	1.8	2.7	2.2
Co 25 + Co 4	41.0	43.2	42.1	1.8	2.1	1.9
Co 25 + CoVu 7	29.5	27.8	28.6	1.2	1.8	1.5
Co 22 + Co 1	45.3	44.1	44.7	3.1	2.8	3.0
Co 22 + Co 4	44.0	44.7	44.3	3.1	1.9	2.5
Co 22 + CoVu 7	26.4	26.8	26.6	1.1	1.8	1.4
	38.7	38.8		2.7	2.6	
		SE _d	CD		SE _d	CD
S		3.03	6.16		0.42	0.85
M		1.43	Ns		0.20	NS
S x M		4.28	NS		0.59	NS

to sole crop DMP (Table 4.14). In the second and third year, the difference in the DMP of intercropped cowpea Co 1 with the two sorghum genotypes was less significant; but intercropped cowpea Co 4 produced lesser DMP with sorghum Co 22 than with sorghum Co 25.

Dry matter production by cowpea in intercropping was unaffected by change in land management from flat bed to bed furrow.

In intercropping systems, the DMP of cowpea increased with N applied at 40 kg ha⁻¹ during the second year; there was however, no improvement in cowpea DMP due to N application in the third year. None of the interactions studied had any significant effect on DMP of intercropped cowpea.

4.2.3. Pods per plant (Table 4.15)

As sole crop, cowpea genotype Co 1 produced more pods per plant than the other two genotypes viz., Co 4 and CoVu 7. The genotype Co 4 had more pods than CoVu 7.

Pod production per plant in intercropping was similar to sole crop in cowpea Co 1 only. In Co 4 and CoVu 7, there was a reduction in pods per plant due to intercropping as compared to their respective sole crops in the first year.

In intercropping also, cowpea Co 1 produced more number of pods per plant over Co 4 and CoVu 7. Within the intercrop combinations with sorghum genotypes, pod production by cowpea Co 1 with both the sorghum genotypes was comparable in the first and second year while in the third year, cowpea Co 1 intercropped with sorghum Co 25 produced more pods than with sorghum Co 22.

Cowpea Co 4 produced more pods per plant in intercropping with sorghum Co 22 than with sorghum Co 25 in the first year. But, in the second and third year, intercropped cowpea Co 4 produced more pods with sorghum Co 25 than with sorghum Co 22.

Cowpea CoVu 7 also produced lesser pods per plant in intercropping and the reduction was more with sorghum Co 25 than with sorghum Co 22.

Pod production by cowpea in sole cropping as well as intercropping was less affected by changes in land management practices.

An increase in pod production by intercropped cowpea was caused by nitrogen application. There was however little difference in pod production by cowpea between 20 and 40 kg N levels in both the years.

4.2.4. Pod length (Table 4.16)

Cowpea Co 4 had longer pods than cowpea Co 1 and CoVu 7 in that order in sole cropping as well as intercropping systems. There was no difference in pod length between sole cropping and intercropping for the individual cowpea genotypes. Within intercrop combinations, pod length of each cowpea genotype remained unaffected due to a change in sorghum genotype.

Land management practices, N application and their interactions with cropping systems caused little change in the pod length of cowpea.

4.2.5. Grain per pod (Table 4.17)

The number of grains per pod was similar in all the cowpea genotypes. Sole cropping or intercropping with either of the two sorghum genotypes did not result in any significant variation in the number of grains per pod in cowpea. Land management practices, application of nitrogen and their interaction with cropping systems caused no perceptible difference in the number of grains per pod of cowpea.

4.2.6. Grain test weight (Table 4.18)

Grain test weight per 100 grains in sole as well as intercropping was higher with cowpea Co 4 over CoVu 7 which in turn produced heavier grains than cowpea Co 1. During the first

Table 4.16. Cowpea pod length in sole and intercropping under land management and nitrogen levels

		Cowpea pod length (cm)								
		83 - 84		84 - 85		85 - 86				
		Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 1 sole		12.6	12.4	12.5	-	-	-	-	-	-
Co 4 sole		14.9	15.0	14.9	-	-	-	-	-	-
CoVu 7 sole		10.9	11.9	11.4	-	-	-	-	-	-
Co 25 + Co 1		12.3	12.1	12.2	12.8	13.1	13.0	12.5	12.8	12.6
Co 25 + Co 4		14.4	15.0	14.7	15.4	15.4	15.4	15.4	15.4	15.4
Co 25 + CoVu 7		10.2	10.5	10.3	-	-	-	-	-	-
Co 22 + Co 1		12.7	13.1	12.9	12.2	12.5	12.3	12.4	12.7	12.5
Co 22 + Co 4		15.4	16.2	15.8	15.5	15.5	15.5	15.5	15.5	15.5
Co 22 + CoVu 7		11.3	11.5	11.4	-	-	-	-	-	-
		12.7	13.1		14.0	14.1		14.0	14.1	
N ₀							14.1			13.9
N ₂₀							14.0			14.1
N ₄₀							14.1			14.1
S		SE _d	CD	SE _d	CD	SE _d	CD	SE _d	CD	SE _d
M		0.56	1.15	0.33	0.71	0.32	0.69	0.32	0.69	0.32
S x M		0.27	NS	0.23	NS	0.23	NS	0.23	NS	NS
N		0.80	NS	0.47	NS	0.46	NS	0.46	NS	NS
		-	-	0.23	NS	0.21	NS	0.21	NS	NS

87

87

Table 4.17. Cowpea grains per pod in sole and intercropping under land management and nitrogen levels

Cowpea grains per pod										
83 - 84			84 - 85			85 - 86				
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	
Co 1 sole	12.8	12.7	12.7	-	-	-	-	-	-	-
Co 4 sole	12.9	12.8	12.8	-	-	-	-	-	-	-
CoVu 7 sole	12.4	12.0	12.2	-	-	-	-	-	-	-
Co 25 + Co 1	12.4	13.0	12.7	12.8	12.7	12.7	12.8	13.2	13.0	
Co 25 + Co 4	12.4	13.2	12.8	13.8	13.7	13.8	13.8	13.7	13.7	
Co 25 + CoVu 7	11.7	11.9	11.8	-	-	-	-	-	-	-
Co 22 + Co 1	12.2	12.4	12.3	12.9	13.4	13.2	12.9	13.2	13.1	
Co 22 + Co 4	12.5	12.5	12.5	12.7	13.7	13.2	12.7	13.8	13.2	
Co 22 + CoVu 7	12.6	12.5	12.5	-	-	-	-	-	-	-
	12.4	12.5		13.0	13.4		13.0	13.5		
N ₀						13.2			13.2	CD
N ₂₀						12.9			13.2	CD
N ₄₀						13.5			13.4	CD
S		0.43	NS		0.77	NS		0.74	NS	∞
M		0.20	NS		0.55	NS		0.52	NS	∞
S x M		0.61	NS		1.10	NS		1.05	NS	∞
N		-	-		0.39	NS		0.34	NS	∞

Table 4.18. Cowpea grain test weight in sole and intercropping under land management and nitrogen levels

Cowpea 100 grain weight (g)										
83 - 84			84 - 85			85 - 86				
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	
Co 1 sole	6.9	6.8	6.9	-	-	-	-	-	-	-
Co 4 sole	11.6	11.3	11.5	-	-	-	-	-	-	-
CoVu 7 sole	9.0	8.9	9.0	-	-	-	-	-	-	-
Co 25 + Co 1	6.6	6.8	6.7	6.7	7.1	6.9	6.9	7.1	7.0	
Co 25 + Co 4	9.6	9.6	9.6	10.7	10.5	10.6	9.9	9.8	9.9	
Co 25 + CoVu 7	8.4	8.5	8.4	-	-	-	-	-	-	
Co 22 + Co 1	6.8	6.4	6.6	6.8	6.8	6.8	6.8	6.8	6.8	
Co 22 + Co 4	10.2	9.9	10.1	10.6	10.2	10.4	10.1	10.0	10.1	
Co 22 + CoVu 7	7.9	8.1	8.0	-	-	-	-	-	-	
	8.6	8.5	8.7	8.7	8.7	8.4	8.4	8.4		
N ₀			8.6						8.3	
N ₂₀			8.7						8.4	
N ₄₀			8.7						8.5	
S	SE _d	CD	SE _d	CD	SE _d	CD	SE _d	CD	SE _d	CD
M	0.27	0.54	0.24	0.51	0.15	0.32	0.10	0.32	0.15	0.32
S x M	0.12	NS	0.17	NS	0.10	NS	0.21	NS	0.10	NS
N	0.38	NS	0.34	NS	0.21	NS	0.18	NS	0.21	NS
	-	-	0.16	NS	0.18	NS				

year, intercropping with sorghum caused reduction in grain test weight in cowpea Co 4 and CoVu 7 but not in cowpea Co 1. Within intercrop combinations, the grain test weight of the cowpea genotypes remained the same with sorghum Co 25 as well as with sorghum Co 22.

Grain test weight of cowpea did not vary between the two land management practices of flat bed sowing and bed furrow sowing in any of the years. Application of nitrogen had little effect on the grain test weight of cowpea genotypes. None of the interactions studied had any effect on this character in the second and third year.

4.2.7. Leaf area per plant (Table 4.19)

Cowpea Co 4 produced more leaf area per plant over cowpea Co 1 in both sole cropping as well as intercropping. In both the cowpea genotypes, leaf area per plant was relatively lesser in intercropping than in sole cropping.

4.2.8. Leaf weight per plant (Table 4.19)

Green leaf weight per plant was higher for cowpea Co 4 than cowpea Co 1 in sole cropping and intercropping systems. Intercropped cowpea recorded lesser leaf weight per plant than the sole crop in both Co 1 and Co 4 genotypes.

Table 4.19. Leaf area and weight per plant and specific leaf area of cowpea in sole and intercropping

(1985 - 86)

	Leaf area per plant (cm ²)	Leaf weight per plant (g)	Specific leaf area
Co 1 sole	544	13.6	40.0
Co 4 sole	653	16.5	39.6
Co 25 + Co 1	231	5.2	44.5
Co 25 + Co 4	353	9.0	39.2
Co 22 + Co 1	257	5.4	47.6
Co 22 + Co 4	329	9.8	33.6

4.2.9. Specific leaf area (Table 4.19)

Specific leaf area value was higher for cowpea Co 1 than cowpea Co 4 in sole cropping and intercropping with sorghum. Cowpea Co 1 showed an increase in the value of specific leaf area in intercropping over sole cropping. Cowpea Co 4 however recorded a lower value of specific leaf area in intercropping with sorghum Co 22.

4.2.10. Grain yield

During the first year cowpea Co 1 and Co 4 produced higher grain yields as sole crop (470 kg ha^{-1} and 415 kg ha^{-1} , respectively) over CoVu 7 (204 kg ha^{-1}). In the second year, cowpea Co 1 (552 kg ha^{-1}) and cowpea Co 4 (531 kg ha^{-1}) gave nearly similar yields in sole cropping. In the third year also, sole crop yields did not vary much between cowpea Co 4 (357 kg ha^{-1}) and cowpea Co 1 (341 kg ha^{-1}). In the second and third year, estimates of sole crop cowpea yield were made from the plots raised outside the experimental layout.

In the first year, the grain yield of cowpea was considerably reduced in intercropping as compared to the respective sole crop yield of the three genotypes (Table 4.20). Intercrop yield of cowpea genotypes as per cent of sole crop yield ranged from 16 to 18 for Co 1, 10 to 13 for Co 4 and 10 to 16 for CoVu 7 genotypes.

Table 4.20. Cowpea grain yield in sole and intercropping under land management and nitrogen levels

		Cowpea grain yield (kg ha ⁻¹)								
		83 - 84			84 - 85			85 - 86		
		Flat bed	Bed turrew	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed turrew	Mean
Co 1 sole		484	457	470	-	-	-	-	-	-
Co 4 sole		396	435	415	-	-	-	-	-	-
CoVu 7 sole		217	192	204	-	-	-	-	-	-
Co 25 + Co 1		75	76	75	127	138	132	83	88	86
Co 25 + Co 4		43	44	43	92	78	85	65	64	64
Co 25 + CoVu 7		22	17	20	-	-	-	-	-	-
Co 22 + Co 1		91	83	87	113	128	121	73	77	75
Co 22 + Co 4		56	57	56	65	67	66	53	52	53
Co 22 + CoVu 7		38	26	32	-	-	-	-	-	-
		158	154		99	103		68	70	
N ₀							89			68
N ₂₀							112			69
N ₄₀							102			70
S		SE _d	SE _d	CD	SE _d	SE _d	CD	SE _d	SE _d	CD
M		17.1	17.1	34.8	6.27	6.27	13.4	2.1	2.1	4.6
S x M		8.1	8.1	NS	4.43	4.43	NS	1.5	1.5	NS
N		24.2	24.2	NS	8.87	8.87	NS	3.0	3.0	NS
		-	-	-	4.28	4.28	8.7	2.4	2.4	NS

94

Cowpea genotypes exhibited significant difference in their yield potential in intercropping systems. Generally, cowpea Co 1 yielded higher than Co 4 in intercropping with sorghum in all the three years of study. Among the three cowpea genotypes compared in the first year, CoVu 7 recorded lower yields (20-32 kg ha⁻¹) than the other two genotypes.

The effect of sorghum genotypes on the yield of intercropped cowpea genotypes varied between the years. Cowpea Co 1 produced comparable yields in association with both sorghum Co 25 and Co 22 in the first two years but gave higher yield with sorghum Co 25 in the third year. Cowpea Co 4 gave similar grain yield with both the sorghum genotypes in the first year but its yield increased in association with sorghum Co 25 than with sorghum Co 22 in the second and third year. The grain yield of cowpea CoVu 7 did not vary much in intercropping with the two sorghum genotypes.

Grain yield of cowpea varied only marginally with the land management practices of flat bed and bed furrow. The interaction between cropping systems and land management practices had little effect on the grain yield of cowpea.

Grain yield of intercropped cowpea increased with N application during 1984-85, the increase being more with 20 kg N than with 40 kg N (Table 4.21). During 1985-86, N application

Table 4.21. Cowpea grain yield (kg ha⁻¹) under nitrogen levels

	1984-85			1985-86		
	N ₀	N ₂₀	N ₄₀	N ₀	N ₂₀	N ₄₀
Co 25 + Co 1	121	145	131	83	85	89
Co 25 + Co 4	75	97	83	65	66	62
Co 22 + Co 1	102	131	129	74	73	76
Co 22 + Co 4	57	75	65	52	53	53
	89	112	102	68	69	70
		SE _d	CD		SE _d	CD
N		4.2	8.7		2.4	NS
S at N		9.4	NS		4.5	NS
N at S		8.5	NS		4.8	NS

Table 4.22. Cowpea grain yield (kg ha⁻¹) under land management and nitrogen levels

	1984-85			1985-86		
	N ₀	N ₂₀	N ₄₀	N ₀	N ₂₀	N ₄₀
Flat bed	85	113	100	68	69	68
Bed furrow	93	112	104	69	69	72
		SE _d	CD		SE _d	CD
M at N		6.64	NS		3.15	NS
N at M		6.06	NS		3.39	NS

did not cause any increase in the yield of intercropped cowpea. The interactions between cropping systems and N application and between land management and N application had no effect on the grain yield of intercropped cowpea (Table 4.22).

4.2.11. Haulms yield (Table 4.23)

Cowpea Co 1 produced greater yield of haulms over Co 4 in 84-85 but cowpea Co 4 recorded more yield of haulms in 85-86. There was significant difference in the haulms yield of intercropped cowpea due to the associated genotype of sorghum. Cowpea Co 1 recorded higher yield of haulms with sorghum Co 25 than with sorghum Co 22 in 84-85 but yielded similarly with both the sorghum genotypes in 85-86. During both years, cowpea Co 4 produced more yield of haulms with sorghum Co 25 than with sorghum Co 22.

The haulms yield of intercropped cowpea varied only marginally between the two land management practices. The interaction effect of cropping systems with land management on cowpea haulms yield was also absent.

Application of N at 40 kg^{-1} resulted in an increase in the yield of cowpea haulms during 84-85 but the yield of haulms remained unaffected by N application in 85-86. The interactions between cropping systems and land management with N application had very little effect on the haulms yield of intercropped cowpea.

Table 4.23. Cowpea haulms yield in sole and intercropping under land management and nitrogen levels

	Cowpea haulms yield (q ha ⁻¹)					
	1984 - 85			1985 - 86		
	Flat bed'	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 + Co 1	3.80	4.14	3.97	1.59	1.69	1.64
Co 25 + Co 4	3.04	2.84	2.94	2.51	2.39	2.45
Co 22 + Co 1	3.50	3.68	3.59	1.42	1.73	1.58
Co 22 + Co 4	2.26	2.33	2.30	1.88	1.97	1.92
	3.15	3.25		1.85	1.94	
N ₀			2.97			1.79
N ₂₀			3.16			1.92
N ₄₀			3.48			1.98
S		0.17	0.37		0.12	0.25
M		0.12	NS		0.08	NS
S x M		0.24	NS		0.16	NS
N		0.13	0.26		0.10	NS

4.2.12. Nitrogen uptake by cowpea (Table 4.24)

The uptake of N by cowpea was higher in cowpea Co 1 intercropped with sorghum Co 25 in 84-85. In 85-86, higher N uptake was recorded by cowpea Co 4 intercropped with sorghum Co 25. In both the years, cowpea Co 4 intercropped with sorghum Co 22 registered lower uptake of N.

Land management practices and their interaction with cropping system did not produce any significant difference in N uptake by intercropped cowpea.

During both the years, the uptake of N by intercropped cowpea increased with the application of N over the control but the difference between 20 and 40 kg levels was not significant.

4.3. Cropping systems

4.3.1. Total dry matter production of cropping systems (Table 4.25)

The total dry matter production per ha was higher in sorghum Co 25 based cropping systems in all the three years over sorghum Co 22 based cropping systems. In the second year, sorghum Co 25 + cowpea Co 1 intercropping system recorded higher total dry matter per ha over sole sorghum Co 25. But, generally total dry matter production in intercropping systems did not vary much from that of sole sorghum within each sorghum genotype.

Table 4.24. Nitrogen uptake by cowpea in intercropping

	N uptake (kg ha ⁻¹)					
	1984 - 85			1985 - 86		
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 + Co 1	10.5	11.3	10.9	5.5	5.8	5.6
Co 25 + Co 4	8.2	7.4	7.8	6.3	6.1	6.2
Co 22 + Co 1	9.6	10.4	10.0	4.8	5.5	5.2
Co 22 + Co 4	6.0	6.2	6.1	4.9	5.1	5.0
	8.5	8.8		5.4	5.6	
N ₀			7.9			5.2
N ₂₀			8.9			5.6
N ₄₀			9.3			5.7
		SE _d	CD		SE _d	CD
S		0.37	0.79		0.23	0.50
M		0.26	NS		0.16	NS
S x M		0.52	NS		0.33	NS
N		0.28	0.57		0.19	0.39

Table 4.25. Total dry matter production in sole sorghum and sorghum-cowpea intercropping

	Total dry matter production at harvest (q ha ⁻¹)											
	83 - 84				84 - 85				85 - 86			
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 Sole	57.1	60.5	58.8	57.7	58.0	57.8	57.8	58.9	58.3			
Co 22 Sole	43.9	42.3	43.1	48.5	50.5	49.5	41.8	43.3	42.5			
Co 25 + Co 1	53.0	58.5	55.8	61.7	61.8	61.8	57.9	58.8	58.3			
Co 25 + Co 4	59.9	59.5	59.7	58.9	59.7	59.3	59.0	60.2	59.6			
Co 25 + CoVu 7	55.5	55.4	55.4	-	-	-	-	-	-			
Co 22 + Co 1	42.3	46.4	44.4	52.1	53.2	52.7	42.4	43.3	42.8			
Co 22 + Co 4	48.8	46.8	47.8	51.0	49.7	50.4	43.0	44.1	43.6			
Co 22 + CoVu 7	43.2	43.9	43.5	-	-	-	-	-	-			
	50.5	51.7		55.0	55.5		50.3	51.4				
N ₀						49.3						45.4
N ₂₀						56.8						51.4
N ₄₀						59.6						55.8
S	SE _d	CD	SE _d	CD	SE _d	CD	SE _d	CD	SE _d	CD	SE _d	CD
M	3.4	6.9	1.9	3.9	1.9	3.9	1.7	3.4	1.7	3.4	1.7	3.4
S x M	1.7	NS	1.1	NS	1.1	NS	0.9	NS	0.9	NS	0.9	NS
N	4.8	NS	2.7	NS	2.7	NS	2.3	NS	2.3	NS	2.3	NS
	-	-	0.6	1.1	0.6	1.1	0.6	1.2	0.6	1.2	0.6	1.2

100

The total DMP of cropping systems was unaffected by change in the land management practice and also by its interaction with the cropping systems.

During the second and third year, total DMP of cropping systems increased with the level of N applied. But the interaction effects of cropping systems with N and land management with N were less perceptible.

4.3.2. Total dry fodder and crude protein yield

The total dry fodder yield in intercropping systems was nearly similar or marginally higher than in sole sorghum, in the various intercrop combinations (Table 4.26). Sorghum Co 25 based cropping systems produced more dry fodder than sorghum Co 22 based cropping systems. The crude protein yield of dry fodder from intercropping systems was higher than from sole sorghum by 4.9 to 12.3 per cent in the second year and by 1.1 to 8.0 per cent in the third year in the various intercrop combinations.

4.3.3. Total nitrogen uptake by cropping systems (Table 4.27)

Sorghum Co 25 based cropping systems registered higher uptake of N over sorghum Co 22 based cropping systems in the second and third year. Increased uptake of N by sorghum - cowpea intercropping over the sole crops of respective sorghum genotypes was seen in the second year only. Sorghum Co 25 + cowpea Co 1

Table 4.26. Total dry fodder yield and crude protein content of fodder in sole and intercropping

Cropping system	Total dry fodder (q ha ⁻¹)		Total crude protein (q ha ⁻¹)		Crude protein percent	
	84-85	85-86	84-85	85-86	84-85	85-86
	Co 25 sole	46.4	50.1	2.59	2.82	5.58
Co 22 sole	39.0	33.0	2.25	2.00	5.77	6.06
Co 25 + Co 1	48.7	49.4	2.91	2.85	5.97	5.77
Co 25 + Co 4	46.4	50.0	2.78	2.94	5.99	5.88
Co 22 + Co 1	40.8	34.1	2.50	2.11	6.13	6.19
Co 22 + Co 4	38.8	34.5	2.36	2.16	6.08	6.26

Table 4.27. Total uptake of nitrogen in sole and intercropping

	Nitrogen uptake (kg ha ⁻¹)					
	1984 - 85			1985 - 86		
	Flat bed	Bed furrow	Mean	Flat bed	Bed furrow	Mean
Co 25 sole	58.6	59.6	59.1	57.7	59.4	58.6
Co 22 sole	51.5	53.2	52.4	46.1	45.8	46.0
Co 25 + Co 1	69.2	69.6	69.4	59.2	61.9	60.5
Co 25 + Co 4	65.1	64.6	64.9	62.9	61.0	62.0
Co 22 + Co 1	59.4	61.7	60.6	50.0	50.9	50.5
Co 22 + Co 4	56.2	56.4	56.3	50.8	50.1	50.5
	60.0	60.8		54.5	54.9	
N ₀			50.9			44.8
N ₂₀			62.7			56.0
N ₄₀			67.6			63.2
		SE _d	CD		SE _d	CD
S		1.46	3.02		2.21	4.58
M		0.84	NS		1.27	NS
S x M		2.06	NS		3.12	NS
N		0.52	1.05		0.71	1.42

followed by sorghum Co 25 + cowpea Co 4 recorded higher N uptake over other intercrop combinations and sole crops of the two sorghum genotypes. In the third year, however, total N uptake by intercropping systems showed only marginal variation from sole sorghum within each sorghum genotype.

Total N uptake by the various cropping systems was less affected by sowing in flat bed or bed furrow.

Application of nitrogen caused a significant increase in the uptake of N by sole sorghum as well as sorghum + cowpea intercropping systems. The total uptake of N increased with increase in the level of N applied from 20 to 40 kg ha⁻¹.

4.3.4. Weed dry weight in sole cropping and intercropping (Table 4.28)

The dry weight of weeds at 40 DS during the first year showed significant variation between the various cropping systems. All the intercrop combinations recorded lower dry weight of weeds than in sole sorghum and sole cowpea plots. Among the intercrop combinations, sorghum Co 25 + cowpea intercropping had lesser dry weight of weeds than sorghum Co 22 + cowpea intercropping system. Among the sole crops of sorghum, the dry weight of weeds varied only slightly between the two sorghum genotypes. But, in cowpea sole cropping, the dry weight of weeds was lesser under sole crop of cowpea Co 4 than in the sole crops of cowpea CoVu 7 and Co 1.

105 105

Table 4.28. Weed dry weight in sole cropping and intercropping (1983-84)

	Weed dry weight at 40 DS (g m^{-2})		
	Flat bed	Bed furrow	Mean
Co 25	11.4	12.7	12.1
Co 22	14.6	13.6	14.1
Co 1	19.0	20.3	19.7
Co 4	13.1	14.1	13.6
CoVu 7	17.7	19.7	18.7
Co 25 + Co 1	8.9	6.4	7.7
Co 25 + Co 4	5.8	6.8	6.3
Co 25 + CoVu 7	7.2	7.1	7.1
Co 22 + Co 1	9.0	12.3	10.7
Co 22 + Co 4	10.1	10.9	10.5
Co 22 + CoVu 7	10.5	9.9	10.2
	11.6	12.2	
	SE_d	CD	
S	1.05	2.13	
M	0.45	NS	
S x M	1.49	NS	

4.3.5. Harvest index of component crops in sole cropping and intercropping (Table 4.29)

The harvest index of each sorghum genotype remained more or less the same in sole sorghum and sorghum-cowpea intercropping systems. Sorghum Co 22 recorded higher value of harvest index over sorghum Co 25 in the third year.

Among the cowpea genotypes, Co 1 registered higher values of harvest index over Co 4 and CoVu 7 in sole cropping as well as intercropping systems in all the three years. During the first year, cowpea genotypes Co 1 and Co 4 recorded relatively lower values of harvest index in intercropping than in sole cropping.

4.3.6. Dry matter distribution between plant parts of sorghum and cowpea in sole and intercropping (Table 4.30)

During the third year (85-86) the distribution of dry matter between various plant parts was assessed for sorghum and cowpea. In sorghum the proportion of stems, leaves and ears remained the same in sole cropping as well as intercropping. While the proportion of dry matter in leaves was the same between the two sorghum genotypes, the proportion of dry matter in stems was higher by 10-14 per cent in sorghum Co 25 over sorghum Co 22. But, the proportion of dry matter in the earheads was higher for sorghum Co 22 than sorghum Co 25. Application of N increased the share of DMP in ears while reducing the proportion of leaf and stem dry matter to total dry matter.

Table 4.29. Harvest index of component crops in sole and intercropping

	Sorghum			Cowpea		
	83-84	84-85	85-86	83-84	84-85	85-86
Sorghum Co 25 sole	-	0.18	0.14	-	-	-
Sorghum Co 22 sole	-	0.19	0.19	-	-	-
Cowpea Co 1 sole	-	-	-	0.38	-	-
Cowpea Co 4 sole	-	-	-	0.31	-	-
Cowpea CoVu 7 sole	-	-	-	0.16	-	-
Co 25 + Co 1	-	0.19	0.14	0.31	0.24	0.30
Co 25 + Co 4	-	0.18	0.14	0.20	0.22	0.17
Co 25 + CoVu 7	-	-	-	0.12	-	-
Co 22 + Co 1	-	0.19	0.21	0.27	0.24	0.25
Co 22 + Co 4	-	0.19	0.20	0.20	0.21	0.18
Co 22 + CoVu 7	-	-	-	0.20	-	-

Table 4.30. Dry matter distribution between plant parts at harvest of component crops in sole and intercropping (1985-86)

	Dry matter distribution between plant parts (%)					
	Sorghum			Cowpea		
	Leaf	Stem	Ear	Leaf	Stem	Pods
Co 25	25	57	17	-	-	-
Co 22	27	46	27	-	-	-
Co 25 + Co 1	25	59	16	17	38	45
Co 25 + Co 1	29	57	14	27	39	34
Co 22 + Co 1	24	45	31	18	35	47
Co 22 + Co 4	24	47	29	27	39	34
N ₀	27	55	18	23	37	40
N ₂₀	25	51	24	22	38	40
N ₄₀	24	51	25	23	38	39

In cowpea, the proportion of leaf dry matter to total dry matter was lesser in cowpea Co 1 than cowpea Co 4. The share of dry matter in stems was the same between the two cowpea genotypes. Cowpea Co 1 had a higher proportion of DMP in the pods by 11 to 13 per cent over cowpea Co.4. Application of nitrogen to intercropping systems caused little difference in the relative proportion of dry matter in leaves, stems and pods of intercropped cowpea.

4.4. Soil moisture content

The available soil moisture content at sowing during the first year was 75.6 mm in 60 cm depth of soil. Subsequent estimations of soil moisture at surface 30 cm layer showed a decline at 60 DS, an increase at 80 DS and a gradual decline at 100 and 120 DS. At all stages of estimation, there was a decrease in soil moisture content in the intercropping systems compared to the sole crop of corresponding sorghum genotype in the first year (Table 4.31).

In the second year (1984-85), the available soil moisture content in 60 cm depth at sowing was 49.0 mm (Table 4.32). From 60 DS onwards, until 120 DS, there was a gradual decline in soil moisture content in the surface 30 cm layer. At all stages of estimation, soil moisture content in intercropping systems was less than that under respective sole sorghum genotype especially during 60 and 80 DS. The reduction in soil moisture was relatively higher in intercropping systems with cowpea Co 1 than with cowpea Co 4.

Table 4.31. Available soil moisture content at different growth stages in sole cropping and intercropping (1983-84)

Cropping system	Available soil moisture (mm per 30 cm)														
	At sowing			At 60 DS			At 80 DS			At 100 DS			At 120 DS		
	FB	BF	M	FB	BF	M	FB	BF	M	FB	BF	M	FB	BF	M
Co 25 sole	36.3	9.0	1.3	5.1	40.1	42.7	41.4	21.7	27.2	24.4	28.3	29.7	29.0		
Co 22 sole	36.3	11.1	7.2	9.1	31.9	36.4	34.1	18.9	24.0	21.4	31.3	35.0	33.1		
Co 1 sole	36.3	2.1	5.7	3.9	37.1	30.9	34.0	22.1	20.0	21.0	28.2	29.0	28.6		
Co 4 sole	36.3	7.9	7.7	7.8	33.5	35.7	34.6	20.4	23.5	21.9	24.8	31.9	28.3		
CoVu 7 sole	36.3	*	*	*	38.2	37.4	37.8	23.1	21.3	22.2	31.0	21.6	26.3		
Co 25 + Co 1	36.3	*	5.2	1.8	31.8	34.1	32.9	18.8	22.9	20.8	31.9	33.5	32.7		
Co 25 + Co 4	36.3	3.9	4.0	3.9	35.5	31.5	33.5	19.7	21.8	20.7	29.0	34.8	31.9		
Co 25 + CoVu 7	36.3	5.1	5.7	5.4	38.0	34.6	36.3	26.1	21.5	23.8	37.0	29.8	33.4		
Co 22 + Co 1	36.3	5.8	6.0	5.9	42.6	40.4	41.5	28.7	27.8	28.2	37.8	38.9	38.3		
Co 22 + Co 4	36.3	1.7	*	0.8	36.8	38.7	37.7	23.1	24.6	23.8	33.4	32.3	32.8		
Co 22 + CoVu 7	36.3	*	*	*	35.5	30.1	32.8	21.7	21.4	21.6	46.0	32.5	39.2		

FB - Flat bed

BF - Bed furrow

M - Mean

* - Below wilting point

Table 4.32. Available soil moisture content at different growth stages in sole cropping and intercropping.

Cropping systems	Soil moisture content (mm per 30 cm)											
	At sowing		At 60 DS		At 85 DS		At 100 DS		At 120 DS			
	FB	M	FB	M	FB	M	FB	M	FB	M	FB	M
1984-85												
Co 25 sole	24.3	40.0	39.8	39.9	30.8	35.6	33.2	23.3	21.6	22.4	16.0	15.4
Co 22 sole	24.3	41.4	35.8	38.5	37.6	31.4	34.5	25.7	22.9	24.4	21.9	17.7
Co 25 + Co 1	24.3	30.3	26.5	28.4	25.4	22.9	24.1	18.7	16.6	17.7	15.2	12.7
Co 25 + Co 4	24.3	37.5	34.1	35.7	31.6	27.7	29.6	23.0	20.1	21.5	18.1	16.0
Co 22 + Co 1	24.3	28.8	23.9	26.3	28.0	15.9	21.9	17.1	14.1	15.6	15.0	11.3
Co 22 + Co 4	24.3	31.7	32.5	32.1	22.7	28.3	25.5	15.9	21.3	18.6	13.7	15.0
1985-86												
Co 25 sole	27.2	10.8	13.7	12.3	12.1	7.8	10.0	*	*	*	*	*
Co 22 sole	27.2	14.0	3.6	8.8	13.9	12.4	13.1	*	*	*	*	*
Co 25 + Co 1	27.2	13.9	5.0	9.4	11.4	9.3	10.3	*	*	*	*	*
Co 25 + Co 4	27.2	8.5	4.0	6.2	7.3	8.1	7.7	*	*	*	*	*
Co 22 + Co 1	27.2	8.8	7.5	8.2	11.9	5.9	8.9	*	*	*	*	*
Co 22 + Co 4	27.2	13.9	4.8	9.3	10.1	6.8	8.4	*	*	*	*	*

FB - Flat bed; BF - Bed furrow; M - Mean

* - Below wilting point

1984
1985
1986

The available soil moisture content at sowing in the third year (1985-86) was 56.5 mm. There was a sharp decline in soil moisture content in the surface 30 cm layer after 80 DS onwards and it was below wilting point till harvest (Table 4.32). In this year also, there was a decrease in soil moisture content in the intercropping systems as compared to sole sorghum, especially in the early stages of estimation at 60 and 80 DS.

In all the three years, the soil moisture per cent in the surface 0-15 cm layer at 60 DS was distinctly lower in bed furrows than in flat beds. At subsequent stages, the variation in soil moisture per cent in 0-15 cm and 15-30 cm layers was not consistent between bed furrow and flat bed system (Table 4.33).

The data on actual soil moisture balance and the estimated balance based on computed values of crop ET are presented in Table 4.34.

Water use by sole sorghum and sorghum-cowpea intercropping systems was calculated from available soil moisture at sowing, effective rainfall and available soil moisture at harvest. A comparison of this quantity of actual water use with the estimated crop evapotranspiration requirement is shown in Table 4.35.

Table 4.33. Soil moisture content (%) in flat bed and furrow

At DS	Depth (cm)	1983-84		1984-85		1985-86	
		FB	BF	FB	BF	FB	BF
60	0 - 15	9.5	8.8	17.5	16.8	12.1	10.4
	15 - 30	11.4	12.2	18.5	17.9	12.8	12.0
80	0 - 15	17.8	17.7	16.7	16.3	10.9	10.6
	15 - 30	19.0	18.7	16.7	15.9	13.6	12.9
100	0 - 15	16.7	17.0	14.2	13.7	5.4	5.3
	15 - 30	18.4	18.3	15.0	14.9	8.0	7.8
120	0 - 15	16.4	16.5	13.2	12.7	7.1	6.9
	15 - 30	18.5	18.4	14.0	13.6	8.7	8.2

FB - Flat bed

BF - Bed furrow

Table 4.34. Estimated and actual soil moisture balance in sole sorghum and sorghum-cowpea intercropping (mm/30 cm)

Cropping system	E	A	E	A	E	A	E	A
	60 DS		80 DS		100 DS		120 DS	
1983-84								
Co 25 sole	7.7	5.3	33.9	41.6	22.4	34.9	13.9	34.2
Co 22 sole	5.0	9.3	38.1	34.3	26.6	31.6	-	33.3
Co 25 + Co 1	7.7	2.0	33.9	33.1	22.4	31.0	13.9	32.9
Co 25 + Co 4	7.7	4.1	33.9	33.7	22.4	30.9	13.9	32.1
Co 22 + Co 1	5.0	6.1	38.1	41.7	26.6	38.4	-	38.5
Co 22 + Co 4	5.0	1.0	38.1	37.9	26.6	34.0	-	33.0
1984-85								
	60 DS		80 DS		100 DS		120 DS	
Co 25 sole	36.0	40.1	29.8	33.4	5.1	22.6	23.1	15.9
Co 22 sole	31.1	38.7	28.1	34.7	5.3	24.6	-	20.0
Co 25 + Co 1	36.0	28.6	29.8	24.3	5.1	17.9	23.1	14.1
Co 25 + Co 4	36.0	35.0	29.8	29.8	5.1	21.7	23.1	17.3
Co 22 + Co 1	31.1	26.5	28.1	22.9	5.3	15.8	-	13.3
Co 22 + Co 4	31.1	32.3	28.1	25.7	5.3	18.3	-	14.5
1985-86								
	73 DS		82 DS		100 DS		116 DS	
Co 25 sole	19.5	12.5	5.1	10.2	*	*	*	*
Co 22 sole	18.0	9.0	7.6	13.3	*	*	*	*
Co 25 + Co 1	19.5	9.6	5.1	10.5	*	*	*	*
Co 25 + Co 4	19.5	6.4	5.1	7.9	*	*	*	*
Co 22 + Co 1	18.0	8.4	7.6	9.1	*	*	*	*
Co 22 + Co 4	18.0	8.7	7.6	8.6	*	*	*	*

E = Estimated A = Actual

* = Below wilting point

Table 4.35. Estimated crop evapotranspiration and actual water use in sole sorghum and sorghum-cowpea intercropping

Cropping System	ASM at sowing (mm/60 cm)	Effective rainfall (mm)	ASM at harvest (mm/60 cm)	Water use (mm)	Estimated crop ET (mm)
1983-84					
Co 25 sole	75.6	207.3	68.9	214.0	254.3
Co 22 sole	75.6	192.5	63.7	204.4	224.7
Co 25 + Co 1	75.6	207.3	66.3	216.6	254.3
Co 25 + Co 4	75.6	207.3	64.7	218.2	254.3
Co 22 + Co 1	75.6	192.5	77.4	190.7	224.7
Co 22 + Co 4	75.6	192.5	68.5	199.6	224.7
1984-85					
Co 25 sole	49.0	288.7	32.0	305.7	292.6
Co 22 sole	49.0	225.0	49.6	224.4	264.6
Co 25 + Co 1	49.0	288.7	28.4	309.3	292.6
Co 25 + Co 4	49.0	288.7	34.9	302.8	292.6
Co 22 + Co 1	49.0	225.0	31.8	242.2	264.6
Co 22 + Co 4	49.0	225.0	36.9	237.1	264.6
1985-86					
Co 25 sole	56.5	223.1	66.5*	213.1	273.6
Co 22 sole	56.5	185.6	60.3*	181.8	244.2
Co 25 + Co 1	56.5	223.1	63.1*	216.5	273.6
Co 25 + Co 4	56.5	223.1	65.9*	213.7	273.6
Co 22 + Co 1	56.5	185.6	56.2*	185.9	244.2
Co 22 + Co 4	56.5	185.6	55.4*	186.7	244.2

ASM - Available soil moisture

* - Total soil moisture content in mm/60 cm

4.5. Yield advantage in sorghum-cowpea intercropping

4.5.1. Actual yield of component crops in intercropping to expected yield based on population (Table 4.36)

In order to assess the effect of competition in intercropping situations, the actual yields of sorghum and cowpea in intercropping were compared with the yield expected based on their relative population in sole cropping and intercropping. The population of sorghum was 1,48,000 plants ha⁻¹ in sole as well as intercropping. For cowpea, the intercrop population (1,11,000 plants ha⁻¹) was 33 per cent of its sole crop population (3,33,000 plants ha⁻¹).

The actual yield of sorghum Co 25 in intercropping ranged from 97 to 103 per cent of expected yield while that of sorghum Co 22 varied from 95 to 101 per cent of expected yield.

Actual yield of intercropped cowpea was less than the yield expected based on its population. The percentage of actual yield to the expected yield from cowpea in intercropping was higher for the genotype Co 1 over Co 4 and CoVu 7. With sorghum Co 25 cowpea Co 1 gave 48 to 77 per cent of expected yield and 56 to 67 per cent with sorghum Co 22. Cowpea Co 4 produced 31 to 54 per cent of expected yield in intercropping with sorghum Co 25 and 38 to 45 per cent with sorghum Co 22. Cowpea CoVu 7 gave 30 per cent of expected yield with sorghum Co 25 and 48 per cent with sorghum Co 22.

Table 4.36. Actual yield of component crops in intercropping as per cent of expected yield based on population

	Sorghum			Cowpea		
	83-84	84-85	85-86	83-84	84-85	85-86
Co 25 + Co 1	-	103	99	48	73	77
Co 25 + Co 4	-	98	97	31	49	54
Co 25 + CoVu 7	-	-	-	30	-	-
Co 22 + Co 1	-	99	100	56	66	67
Co 22 + Co 4	-	95	101	41	38	45
Co 22 + CoVu 7	-	-	-	48	-	-

4.5.2. Land equivalent ratio (Table 4.37)

The land equivalent ratio (LER) of cowpea in intercropping was higher for cowpea Co 1 than cowpea Co 4 in all the years. The LER values of cowpea ranged from 0.22 to 0.25 for cowpea Co 1 and from 0.12 to 0.18 for cowpea Co 4. There was a slight increase in the LER of both varieties in intercropping with sorghum Co 25 as compared to that with sorghum Co 22.

The LER of intercropped cowpea did not vary much between the two land management practices of flat bed sowing and bed furrow sowing. There was an increase in the LER of cowpea due to application of nitrogen in the second year but no such beneficial effect was seen in the third year.

The LER of sorghum Co 25 in intercropping with cowpea ranged from 0.97 to 1.03 and that of sorghum Co 22 from 0.96 to 1.01. There was a marginal increase (0.02) in LER of sorghum in bed furrow sowing over flat bed sowing. Application of nitrogen caused a significant improvement in the values of LER of sorghum. At 20 kg N application, the LER of intercropped sorghum increased by 0.11 to 0.20 over no nitrogen application. The increase in LER at 40 kg N over no nitrogen varied from 0.17 to 0.25.

The land equivalent ratio of the various intercrop combinations ranged from 1.08 to 1.27 in the two years. Among the different

Table 4.37. Land equivalent ratio of intercropping as influenced by genotypes, land management and nitrogen levels

	1984-85		1985-86	
	LER _C	LER _S	LER _C	LER _S
Co 25 + Co 1	0.24	1.03	0.25	0.99
Co 25 + Co 4	0.16	0.98	0.18	0.97
Co 22 + Co 1	0.22	0.99	0.22	1.00
Co 22 + Co 4	0.12	0.96	0.15	1.01
Flat bed	0.18	0.98	0.20	0.98
Bed furrow	0.19	1.00	0.20	1.00
N ₀	0.16	0.90	0.20	0.81
N ₂₀	0.21	1.01	0.20	1.01
N ₄₀	0.19	1.07	0.20	1.16

LER_C = LER of cowpea LER_S = LER of sorghum

combinations of genotypes of sorghum and cowpea, higher LER values were recorded by sorghum Co 25 + cowpea Co 1 intercropping (1.24 - 1.27) and it was followed by sorghum Co 22 + cowpea Co 1 (1.21 to 1.22), sorghum Co 25 + cowpea Co 4 (1.14 to 1.15) and sorghum Co 22 + cowpea Co 4 (1.08 to 1.16) in that order.

The land equivalent ratio of sorghum - cowpea intercropping marginally increased (0.02 - 0.03) in bed furrow sowing over flat bed sowing. The addition of N at 20 and 40 kg levels caused a substantial increase in the LER of sorghum - cowpea intercropping in both the years. The increase in LER due to application of 20 kg N ha⁻¹ was 0.16 in 1984-85 and 0.20 in 1985-86; corresponding increase in LER values for 40 kg N ha⁻¹ were 0.20 and 0.35 respectively.

4.6. Competitive ability of component crops in intercropping

4.6.1. Relative crowding coefficient (Table 4.38)

The relative crowding coefficient (RCC) values of the two sorghum genotypes were generally higher when intercropped with cowpea Co 1 than with cowpea Co 4. Between the two sorghum genotypes, sorghum Co 22 recorded relatively higher RCC values than sorghum Co 25.

Among the three cowpea genotypes, cowpea Co 1 recorded consistently higher values of RCC over Co 4 and CoVu 7. The effect of associated sorghum genotypes on the RCC values of cowpea genotypes

varied between the years. During 1983-84, all the three cowpea genotypes registered higher values of RCC with sorghum Co 22 than with sorghum Co 25. In 1984-85 and 1985-86, association with sorghum Co 25 increased the RCC of both cowpea Co 1 and Co 4 as compared to the intercropping with sorghum Co 22.

4.6.2. Aggressivity (Table 4.38)

Sorghum recorded positive values of aggressivity as against the negative values of aggressivity by cowpea. The aggressivity of both the sorghum genotypes was higher with cowpea Co 4 than with cowpea Co 1 in both the years.

Though both the cowpea genotypes recorded negative values of aggressivity, the negative values were lesser for cowpea Co 1 than for cowpea Co 4. The aggressivity of cowpea Co 1 did not show much variation in association with both sorghum Co 25 and Co 22. But, cowpea Co 4 recorded less negative values of aggressivity with sorghum Co 25 than with sorghum Co 22.

4.6.3. Competition Ratio (Table 4.38)

The competition ratio values of sorghum were much higher than that of cowpea in the various intercrop combinations. The CR value of sorghum Co 22 (2.26 to 3.85) were relatively higher than those of sorghum Co 25 (1.96 to 3.97). Both the sorghum genotypes recorded higher values of CR with cowpea Co 4 than with cowpea Co 1.

Table 4.38. Competitive ability of component crops in intercropping

	Relative crowding coefficient					
	Sorghum			Cowpea		
	83-84	84-85	85-86	83-84	84-85	85-86
Co 25 + Co 1	-	14.6	43.4	0.38	0.63	0.67
Co 25 + Co 4	-	30.2	17.4	0.23	0.38	0.44
Co 25 + CoVu 7	-	-	-	0.22	-	-
Co 22 + Co 1	-	51.2	206.2	0.45	0.56	0.56
Co 22 + Co 4	-	10.8	69.4	0.31	0.28	0.35
Co 22 + CoVu 7	-	-	-	0.37	-	-

	Aggressivity			
	Sorghum		Cowpea	
	84-85	85-86	84-85	85-86
Co 25 + Co 1	0.31	0.22	-0.31	-0.22
Co 25 + Co 4	0.50	0.43	-0.50	-0.43
Co 22 + Co 1	0.32	0.33	-0.32	-0.33
Co 22 + Co 4	0.58	0.56	-0.58	-0.56

	Competition Ratio			
	Sorghum		Cowpea	
	84-85	85-86	84-85	85-86
Co 25 + Co 1	2.16	1.96	0.46	0.51
Co 25 + Co 4	3.07	2.71	0.32	0.37
Co 22 + Co 1	2.26	2.27	0.44	0.44
Co 22 + Co 4	3.85	3.40	0.26	0.29

Cowpea Co 1 registered higher values of CR (0.44 to 0.51) than cowpea Co 4 (0.26 to 0.37). The CR value of cowpea Co 1 showed negligible difference with the two sorghum genotypes. But, cowpea Co 4 recorded higher values of CR with sorghum Co 25 than with sorghum Co 22.

4.7. Cost and returns of sole sorghum and sorghum cowpea intercropping (Table 4.39)

During 1983-84, sole cowpea Co 1 and Co 4 alone gave profitable returns. Sole sorghum and all the intercropping systems resulted in loss only. The extent of loss, however, was reduced in intercropping systems involving cowpea Co 1 and Co 4.

During 1984-85 and 1985-86, all the intercrop combinations gave higher gross and net returns over sole crops of respective sorghum genotypes. The cost benefit also was higher in sorghum cowpea intercropping than sole sorghum.

The combination of sorghum Co 25 + cowpea Co 1 gave higher net returns and increased cost benefit consistently in both the years. Within each sorghum genotype, intercropping with cowpea Co 1 resulted in higher net returns over the association with cowpea Co 4. Sorghum Co 25 based cropping systems were more remunerative than sorghum Co 22 based cropping systems.

Table 4.39. Cost and returns from sole and intercropping systems

Cropping system and management practices	1983-84			1984-85			1985-86					
	Cost	Gross return	Net return	Cost	Gross return	Net return	Cost	Gross return	Net return			
	Rs	ha ⁻¹	Rs	ha ⁻¹	Rs	ha ⁻¹	Rs	ha ⁻¹	Rs	ha ⁻¹		
			benefit			benefit			benefit			
Co 25 sole	1433	588	-845	0.41	1455	2972	1517	2.04	1455	2397	942	1.65
Co 22 sole	1433	431	-1002	0.30	1455	2625	1170	1.80	1455	2315	860	1.59
Co 25 + Co 1	1527	898	-629	0.59	1550	3699	2149	2.39	1550	2762	1212	1.78
Co 25 + Co 4	1527	707	-730	0.52	1550	3330	1780	2.15	1550	2645	1095	1.71
Co 22 + Co 1	1527	837	-690	0.55	1550	3179	1629	2.05	1550	2663	1113	1.72
Co 22 + Co 4	1527	736	-791	0.48	1550	2831	1281	1.83	1550	2589	1039	1.67
Flat bed	1452	990	-462	0.68	1468	3059	1591	2.08	1468	2551	1083	1.74
Bed furrow	1552	979	-573	0.63	1568	3154	1586	2.01	1568	2561	993	1.63
N ₀					1413	2810	1397	1.99	1413	2154	741	1.52
N ₂₀					1523	3172	1649	2.08	1523	2599	1076	1.71
N ₄₀					1618	3336	1718	2.06	1618	2933	1315	1.81

124
124

Though gross returns were similar between the two land management practices, the net return and cost benefit were marginally higher in flat bed sowing over bed furrow sowing.

The net returns were substantially increased with the application of N and led to the realisation of increased cost benefit with N fertilizer use. Gross returns as well as net returns were higher at 40 kg level than at 20 kg level.

4.8. Correlations and regression

4.8.1. Cowpea yield and growth characters in sole crop

The value of correlation coefficient (r) of the association between cowpea growth characters among themselves and with yield in sole cropping are presented in Table 4.40.

4.8.2. Cowpea yield and growth characters in intercropping

Correlation coefficient for the relationship between growth characters of cowpea in intercropping and with grain yield are shown in Table 4.41 and 4.42.

4.8.3. Regression of sole crop cowpea characters on intercrop cowpea characters

Univariate regression of sole crop cowpea characters such as yield, plant height, pods per plant, pod length, grains per pod, grain test weight, DMP at harvest and harvest index and corresponding characters in intercrop cowpea are presented in Table 4.44.

Table 4.40. Correlation coefficient between yield and growth characters in sole crop cowpea (1983-84)

Parameters	Grain	Height	DMP	Pods/ plant	Pod length	Grains /pod	Grain weight
Grain yield	1	0.7563*	0.0512	0.6318*	0.4699*	-0.0072	-0.1047
Height		1	0.2522	0.6696*	0.1793	0.1678	-0.4888*
DMP			1	0.1010	0.2862	-0.1693	0.2772
Pods/plant				1	0.1254	0.1406	-0.2631
Pod/length					1	0.5292*	0.5285*
Grains/pod						1	-0.0577
Grain weight							1

* Significant at 5% level

126

126

Table 4.41. Correlation coefficient between yield and growth characters of intercropped cowpea (1983-84)

Parameter	Grain yield	Height	DMP	Pods/ plant	Pod length	Grains per pod	Grain weight
Grain yield	1	0.7078*	0.5724*	0.7966*	0.3067	0.1469	-0.4819*
Height		1	0.5146*	0.5056*	0.5503*	0.2225	-0.0131
DMP			1	0.3672*	0.3855*	0.0458	-0.1094
Pods/plant				1	-0.0963	0.1592	-0.7608*
Pod length					1	-0.0580	0.5076*
Grain/pod						1	0.1242
Grain weight							1

* Significant at 5% level

Table 4.42. Correlation coefficient between growth characters and yield of intercropped cowpea

Parameter	Grain yield	DMP	Pods / plant	Pod length	Grains per pod	Grain weight
1984-85						
Grain yield	1	0.8294*	0.9091*	-0.7904*	-0.1048	-0.8329*
DMP		1	0.8381*	-0.6787*	-0.2396	-0.8097*
Pods/plant			1	-0.8631*	-0.2383	-0.8852*
Pod length				1	0.2720	0.9619*
Grains/pod					1	0.2682
Grain weight						1
1985-86						
Grain yield	1	-0.1635	0.8681*	-0.3111	-0.1911	-0.8424*
DMP		1	-0.0497	0.4048*	0.3752	0.4204
Pods/plant			1	-0.8165	-0.2182	-0.8234*
Pod length				1	0.3576	0.9761*
Grains/pod					1	0.2777
Grain weight						1

* Significant at 5% level

128

42
00

4.8.4. Correlation between sorghum growth characters on cowpea yield in intercropping

The correlation coefficients for the relationship between sorghum growth characters and cowpea yield in intercropping are presented in Table 4.43.

4.8.5. Correlation between cowpea competition ratio and the growth characters of cowpea and sorghum

The competition ratio of intercropped cowpea was correlated to the growth characters of cowpea and sorghum in intercropping to identify characters influencing cowpea competitiveness in intercropping. The correlation coefficients are shown in Table 4.45.

4.8.6. Correlation between competition function values and yield of sorghum and cowpea in intercropping

The values of competition functions such as relative crowding coefficient, aggressivity and competition ratio of the two component crops were correlated to the actual yield of the crops in intercropping system. The coefficients of these correlations are presented in Table 4.46.

Table 4.43. Correlation between sorghum growth characters and yield of intercropped cowpea

Sorghum growth character	Correlation coefficient 'r'		
	1983-84	1984-85	1985-86
Height	-0.2120	0.2506	0.5153*
Leaves per plant	-0.2674	0.2718	0.5065*
LAI at flowering	-0.3140	0.3665	0.5411*
DMP at flowering	-0.3463	-	-
DMP at harvest	-0.1094	0.4058*	0.3932

Table 4.44. Correlation between cowpea growth characters in sole cropping and intercropping

Growth character	'r'	'b'	'a'
Grain yield	0.7872*	0.158'	-5.56
Height	0.6771*	0.852	6.02
DMP	-0.0380	-0.046	2.27
Pods/plant	0.6105*	1.171	-1.87'
Pod length	0.7341*	0.869	1.65
Grains per pod	0.2714	0.317	6.39
Grain test weight	0.9419*	0.667	21.62
Harvest index	0.8033*	0.714	0.003

* Significant at 5% level

Table 4.45. Regression of growth characters of cowpea and sorghum on the competition ratio of cowpea

Growth character of cowpea/sorghum	'r'	'b'	a
Cowpea			
DMP at harvest	0.3414	0.03	0.27
Pods per plant	0.8712**	0.094	0.012
Grain test weight	-0.8846**	-0.044	0.77
Harvest index	0.7618**	1.66	0.007
Duration	0.7300**	0.009	-0.38
Sorghum			
Height at harvest	0.3980	0.001	0.25
Leaves per plant	0.4165	0.046	0.07
Leaf area index	0.4486	0.061	0.16
DMP at harvest	0.2922	0.004	0.197
Duration	0.3020	0.003	0.025

** Significant at 1% level

Table 4.46. Correlation of competition function values with actual yield of component crops in intercropping

Competition function	Correlation coefficient ('r') with	
	Sorghum yield	Cowpea yield
Relative crowding coefficient	-0.3293	0.6573*
Aggressivity	0.0570	0.6168*
Competition Ratio	0.0079	0.6175*

* Significant at 5% level

DISCUSSION

5. DISCUSSION

The salient findings from the results obtained in the study on rainfed sorghum - cowpea intercropping and presented in chapter 4 are discussed here.

5.1. Yield of component crops in intercropping

5.1.1. Sorghum yield in sole cropping and intercropping

An important question usually raised in intercropping is the possibility of any adverse effect on the yield of base crop cereal by intercropping a legume. The results from this study are only added evidence to earlier findings that a near 'full' yield of sorghum could be obtained in intercropping with legumes such as cowpea (Kunasekaran et al., 1980; Natarajan and Willey, 1981; Anon., 1982; Gangwar, 1986). The compatibility of cowpea as an intercrop with rainfed sorghum is evident from the fact that most of the growth characters and yield attributes of sorghum remained unaffected in intercropping with cowpea. According to Baker (1981), the yield of the determinate component cereal was similar in sole and intercropping in additive mixtures of crops of different phenological groups.

5.1.1.1. Sorghum genotypes and sorghum yield in intercropping

In this study, two genotypes of sorghum were evaluated. They differed mainly in height and duration. Sorghum Co 25 is a medium tall, medium duration (120 days) variety whereas, sorghum Co 22 is a dwarf, short duration (100 days) variety. The inherent

genetic differences between the two genotypes in their growth characters such as duration, height, leaves and leaf area index, were reflected in intercropping also. Thus sorghum Co 25 was taller with more leaves and larger leaf area than sorghum Co 22 in sole as well as intercropping systems.

The variation in the yield of the two genotypes in intercropping was mainly due to the quantity and distribution of rainfall in the three years rather than the effect of intercrop competition (Fig. 5.1). Thus, in the first year, though the seasonal rainfall quantity (302 mm) was near normal, a continuous wet spell during 65 - 72 DS coinciding with the flowering phase of sorghum Co 25 and the early grain development stage of sorghum Co 22 adversely affected grain setting and development and resulted in chaffy heads. In the second year, with both the quantity (563 mm) and distribution of rainfall (25 rainy days) being normal, the medium duration sorghum Co 25 gave higher grain yield over short duration sorghum Co 22. The third year was characterised by low rainfall as well as early cessation of rainfall and both the genotypes yielded less than the previous year. There was a long dry spell from 65 DS and available soil moisture content receded below wilting point after 80 DS. The occurrence of such end-of-season drought was found to reduce the yield of late (125 days) tall sorghum to a greater degree than early (90-100 days) dwarf sorghum genotype. In intercropping studies at ICRISAT, Rao and Willey (1983) reported similar effects of the late dry spells on the yield of long duration sorghum.

In spite of the differences in the rainfall quantity and distribution between the years, sorghum Co 25 produced more straw than sorghum Co 22, obviously due to its taller nature and longer duration for dry matter accumulation. This aspect of greater fodder production by sorghum Co 25 is significant in an animal - oriented dryland farming system and would probably favour the choice of a taller genotype of sorghum in intercropping situations.

5.1.1.2. Cowpea genotypes and sorghum yield in intercropping

Three cowpea genotypes differing in duration, height, growth habit and yield potential were evaluated in this study. The absence of any differential effect of cowpea genotypes on the yield of sorghum in intercropping suggests that variation in duration (early or late) height (tall or dwarf), growth habit (erect, spreading or climbing) or yield potential between cowpea genotypes had little influence on the growth and yield of sorghum in intercropping with cowpea. This may be due to the greater competitiveness of sorghum. Similar findings that the differences in duration of cowpea or other legumes had little effect on sorghum yield were reported earlier (Anon., 1982; Anon., 1988).

5.1.1.3. Competitiveness of sorghum genotypes in intercropping

From the values of the competition functions, it would seem that the early dwarf sorghum (Co 22) was more competitive than the late, tall sorghum (Co 25). Again, considering these values,

both the sorghum genotypes ought to have yielded more with cowpea Co 4 than with cowpea Co 1. But the actual yield trends of sorghum genotypes in intercropping did not support these contentions. Sorghum, in general, was more dominant and the competition from cowpea was too minimal to cause any differential effect on the performance of the two sorghum genotypes. The yield variation between the two sorghum genotypes in sole as well as intercropping was caused mainly by the rainfall quantity and distribution.

Therefore, the competition function values of the sorghum genotypes can be taken to indicate the degree of competition stress for cowpea from the two sorghum genotypes. Accordingly, the cowpea crop experienced more competition from early dwarf sorghum and its yield was less with such genotype (sorghum Co 22) than with the late, tall sorghum (Co 25).

5.1.2. Cowpea yield in sole cropping and intercropping

Cowpea yield in intercropping was considerably reduced in comparison to sole crop yields. In intercropping situations of 2:1 proportion of sorghum and cowpea, a reduction in cowpea yield was inevitable because of the lower plant density in intercropping. In this study, the intercrop cowpea population was only 111 thousand plants per ha as compared to 333 thousand plants per ha in sole cropping. On the basis of population, the yield of intercropped cowpea could not be normally expected to exceed 33 per cent of

sole crop yield. It has earlier been established that legume production in intercropping was more dependent on population (Faris et al., 1983; ICRISAT, 1987b).

Yet, it was observed that the actual yield of intercropped cowpea was lesser than the 'expected' yield based on population. This suggests that, besides a reduced plant density, competition with sorghum has affected the yield of intercropped cowpea. This competition resulted in reduction in the growth parameters per plant such as DMP and pods per plant. The lower than sole crop performance by cowpea in intercropping is thus due to a combination of lesser plant density as well as reduced growth due to possible competition with sorghum. The results observed add evidence to the view that legume yields were generally decreased in intercropping with cereals (Ofori and Stern, 1987; Takur and Bora, 1987).

5.1.2.1. Sorghum genotypes and cowpea yield in intercropping

The effect of sorghum genotypes over the yield of intercropped cowpea was inconsistent over the years. The yield of intercropped cowpea either remained the same with the late tall and early dwarf sorghum genotypes or was higher with late tall sorghum Co 25 than with early dwarf sorghum Co 22.

The obvious inference from the yield trend of intercropped cowpea under the two sorghum genotypes was that light transmission

through sorghum canopy was not a major limiting factor for cowpea yield in intercropping under rainfed conditions. If it were so, cowpea yield under the late tall sorghum with more leaves and larger LAI ought to have been lesser than with the early dwarf sorghum. The reduction in the yield of intercropped cowpea with the early dwarf sorghum could then be considered as an evidence for the importance of the overlapping of critical stages of growth of the two component crops in intercropping systems.

The most sensitive phase of sorghum growth to moisture stress has been identified as the period from post anthesis to early grain filling stage (Sharma et al., 1982). In cowpea, stress for moisture during flowering and pod filling stage has been found to reduce cowpea yield to a greater extent (Turk et al., 1980). Stress becomes all the more severe in intensity if the critical phases for moisture requirement of the component crops occur simultaneously. This happened in the association between cowpea and early dwarf sorghum Co 22 and was reflected in reduced grain yield of cowpea with the early maturing sorghum. Under similar conditions of moisture availability, intercropped cowpea yielded relatively more with late maturing sorghum Co 25. This was so because the competition for available resources was likely to be less severe when the peak requirement stages of the component crops occurred at different times, as observed by Chinnappan and Palaniappan (1980). Also, when moisture was limiting as it happened in the third year of the study, the

competition for light might be a less important factor in intercropping (Reddy et al., 1980). This conclusion is supported by the weak correlation observed between sorghum characters influencing light transmission through the canopy (height, leaves, LAI) and the yield of intercropped cowpea. These results lead to the inference that in rainfed sorghum-cowpea intercropping duration difference between sorghum and cowpea may be more important than the height or canopy characters of sorghum genotypes, in influencing cowpea yield in intercropping.

5.1.2.2. Cowpea genotypes and cowpea yield in intercropping

As explained earlier, all the cowpea genotypes yielded less in intercropping than their respective sole crop yields. But the point of greater interest was the variation in the extent of yield reduction between the three cowpea genotypes which would be an indication of their relative competitiveness in intercropping.

The yield reduction due to intercropping was more severe in cowpea CoVu 7 than in Co 1 or Co 4. Apparently, the erect habit and short height of the genotype CoVu 7 resulted in a reduced plant size (product of canopy width and height). This caused a low dry matter accumulation during the vegetative phase preceding pod formulation and resulted in poor pod development and consequent lower yield in intercropping. Wien and Smithson (1981) attributed the reduced plant size of erect cowpea genotypes as a cause of their less vigorous

growth in intercropping. Greater reduction in the yield of early maturing erect cowpea in intercropping as compared to late maturing prostrate and indeterminate cultivars has been observed in studies at ICRISAT (1987a). Consequent on its low yield in the first year, cowpea CoVu 7 was excluded in the subsequent years of study.

Lower yield potential of pulses genotypes in sole cropping has been related to poor performance in intercropping situation also (Willey and Rao, 1981). The lower yield of cowpea CoVu 7 in intercropping was due to its low yield potential in sole cropping.

The positive correlation between sole crop yield and intercrop yield (Fig. 5.5) suggested that high yield in sole cropping would guarantee high yield in intercropping also. But, this is likely to be affected by genotype differences. For instance, cowpea Co 1 and Co 4 gave near similar high yields in sole cropping; but, in intercropping, cowpea Co 1 gave consistently higher yields than cowpea Co 4. Obviously, the high yielding ability of various cowpea genotypes in sole cropping was likely to be differentially affected in the altered environment of intercropping systems. This points towards the importance of relative competitiveness of cowpea genotypes in intercropping and the need to identify the factors affecting cowpea competitiveness in intercropping.

5.1.2.3. Competitive ability of cowpea genotypes

On the basis of the competition ratio function, the late maturing, climbing cowpea Co 1 was more competitive than the early maturing, spreading cowpea Co 4. This greater competitiveness of cowpea Co 1 was consistent in all the years and also with sorghum genotypes differing in height and duration. Better performance of climbing genotypes of cowpea in intercropping with maize was reported by Adetiloye (1980). The reasons for the greater competitiveness of cowpea Co 1 could be examined from the relationship between the growth characters and the yield of cowpea in intercropping.

a) Cowpea growth characters and yield in intercropping

The pod production per plant was the major determinant of the yield of cowpea (Fig. 5.2) as observed in many other studies too (Chauhan and Joshi, 1980; Pandey et al., 1981). Cowpea Co 1 which produced more pods per plant in intercropping with any sorghum genotype naturally yielded more than the other cowpea genotypes.

Uprety et al. (1979) observed that yield variation between cowpea cultivars was dependent on biomass production. Except in the dry year, cowpea yield in intercropping depended on the ability of the cowpea genotypes to produce more DMP. Presumably, the effect of high DMP on yield was reflected through pod production since a strong correlation was seen between DMP and pods per plant in atleast two years of the study (Fig. 5.3). Littleton et al. (1979)

FIG. 5 2 PODS PER PLANT AND INTERCROP COWPEA YIELD

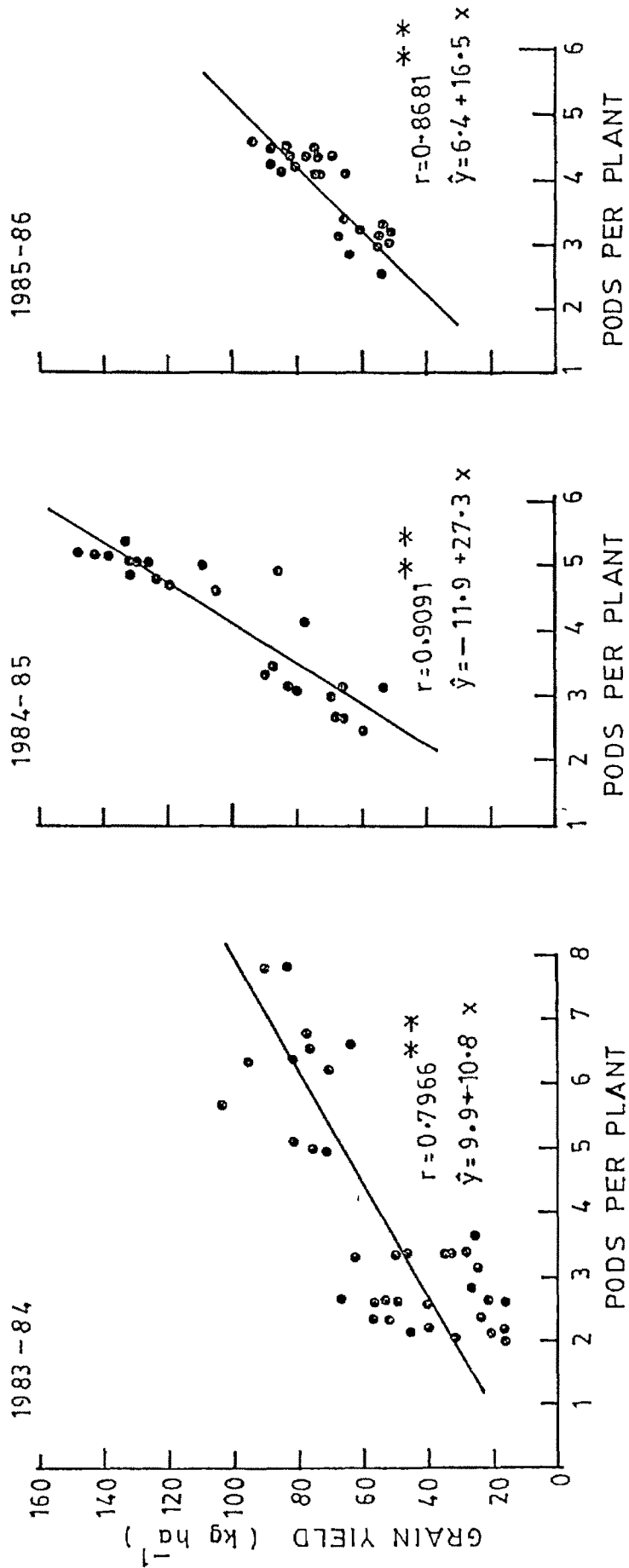
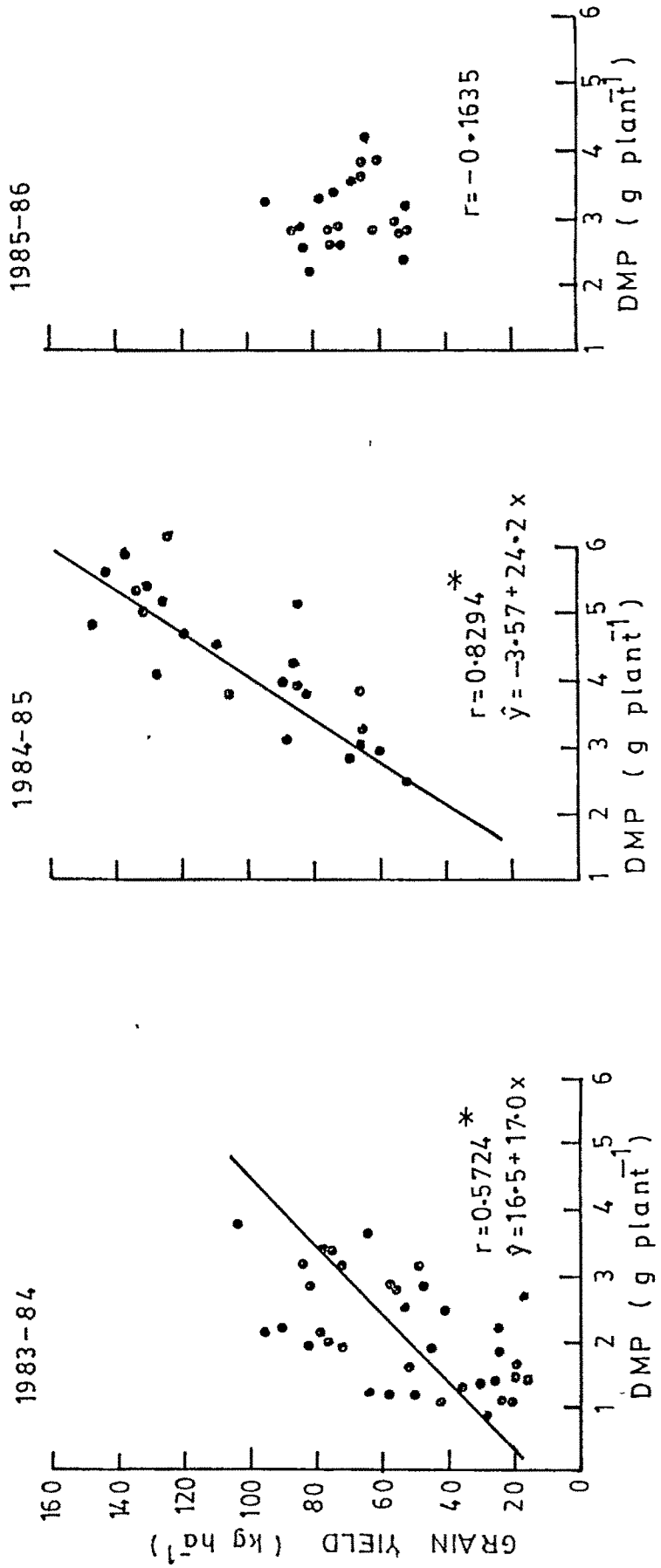


FIG 5.3 DRY MATTER AND GRAIN YIELD OF INTERCROP COWPEA



observed that the number of pods in cowpea was strongly related to total plant dry weight.

The dry matter distribution between plant parts of cowpea at harvest showed that dry matter retained in the vegetative parts (leaves and stems) was lesser in cowpea Co 1 (53-55 per cent) than in cowpea Co 4 (66 per cent). Correspondingly the proportion of pod DMP was higher in cowpea Co 1 (45 per cent) than in cowpea Co 4 (34 per cent). This indicated that there was a greater remobilisation of photosynthates from vegetative parts to the reproductive parts leading to higher grain yield in cowpea Co 1. Balasubramanian (1983) emphasised the importance of such remobilisation of dry matter for higher yield in cowpea. The relatively higher values of harvest index achieved by cowpea Co 1 in intercropping also support this contention.

The positive correlation of plant height with cowpea yield in intercropping (Fig. 5.4) can be interpreted in terms of the ability to support more pods per plant with increase in height. In path analysis studies with cowpea (Hanchinal, 1979; Natarajarathnam ^{et al}, 1985) the canopy height was reported to produce an indirect effect on yield through the direct effect on pod clusters and pods per plant in cowpea. The tall genotype, Co 1 was able to produce more pods per plant than the spreading genotype Co 4 or the short erect genotype CoVu 7.

FIG. 5.4 HEIGHT AND YIELD OF INTERCROP COWPEA

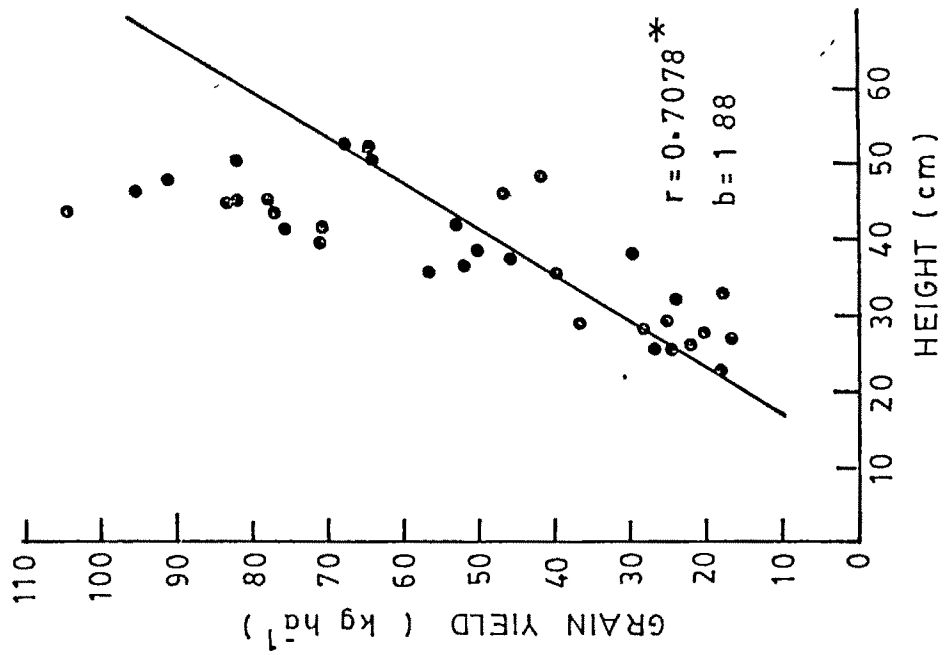
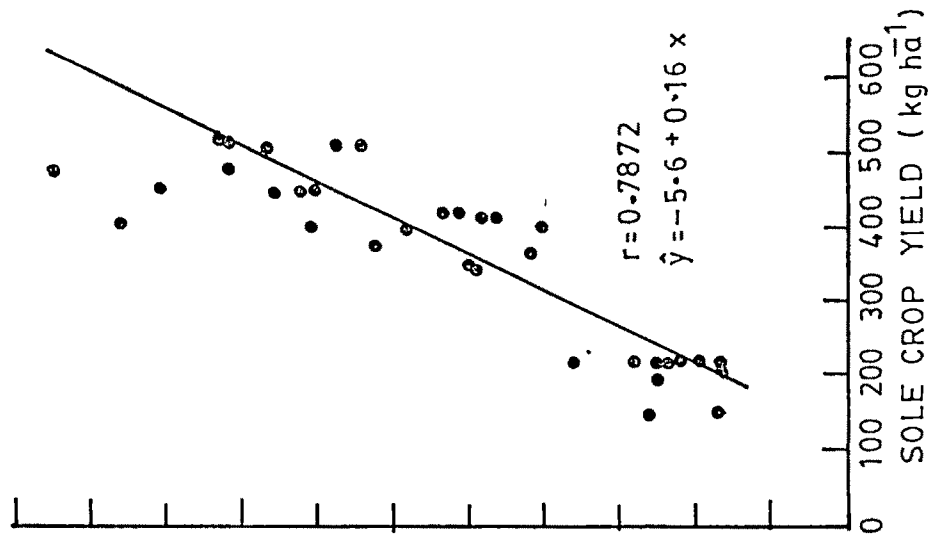


FIG. 5.5 COWPEA-SOLE CROP YIELD AND INTERCROP YIELD



Plant height is a factor of significance for light interception also. The tendency of plants growing under shade to become taller is only an adaptation for the low light intensity conditions. With lesser light transmission through sorghum canopy, the intercropped cowpea with leaf area spread over a taller canopy might be able to intercept more light. The taller genotype Co 1 was thus better equipped for intercropping than the short, erect CoVu 7 or the spreading genotype Co 4.

Low light intensity through shading by sorghum caused the reduced growth vigour of intercropped cowpea (Selvaraj, 1978). So, an improvement in a character associated with shade tolerance would enhance the competitiveness of cowpea in intercropping. Greater specific leaf area (leaf area to leaf weight ratio) was found to be an adaptation to lower light intensity (Blackman, 1956). This could probably explain why cowpea Co 1 with a higher value of specific leaf area yielded better than cowpea Co 4 in intercropping.

The negative relationship of grain test weight with cowpea grain yield under intercropping system observed in this study has to be viewed from the importance of current photosynthesis during pod filling to the final yield of cowpea and other pulses (Kuo et al., 1978). Longer pods and heavier grain weight of cowpea Co 4 meant that a higher pod weight had to be supported by dry matter production during pod filling. When DMP was limited by competition with sorghum,

pod filling and grain development might have been affected in cowpea Co 4. Chandrababu *et al.* (1985) observed that pulses genotypes with high photosynthetic rate at pod development stage might give high yield due to increased sink demand during this stage. The significant reduction in the grain test weight of cowpea Co 4 in intercropping than in sole cropping proved that grain filling was affected due to less dry matter available at this stage.

The positive relationship of cowpea competition ratio with pods/plant and harvest index and its negative relationship with grain test weight reflect the changes in these agronomic characters and their relation to the economic yield of intercropped cowpea, as outlined earlier.

Thus, cowpea Co 1 with greater height, larger specific leaf area, higher DMP, more pods per plant, smaller grains, high harvest index and greater remobilisation of dry matter from vegetative to reproductive parts was able to yield more than cowpea Co 4 and CoVu 7 in intercropping with sorghum.

b) Sorghum growth characters and the competitiveness of cowpea

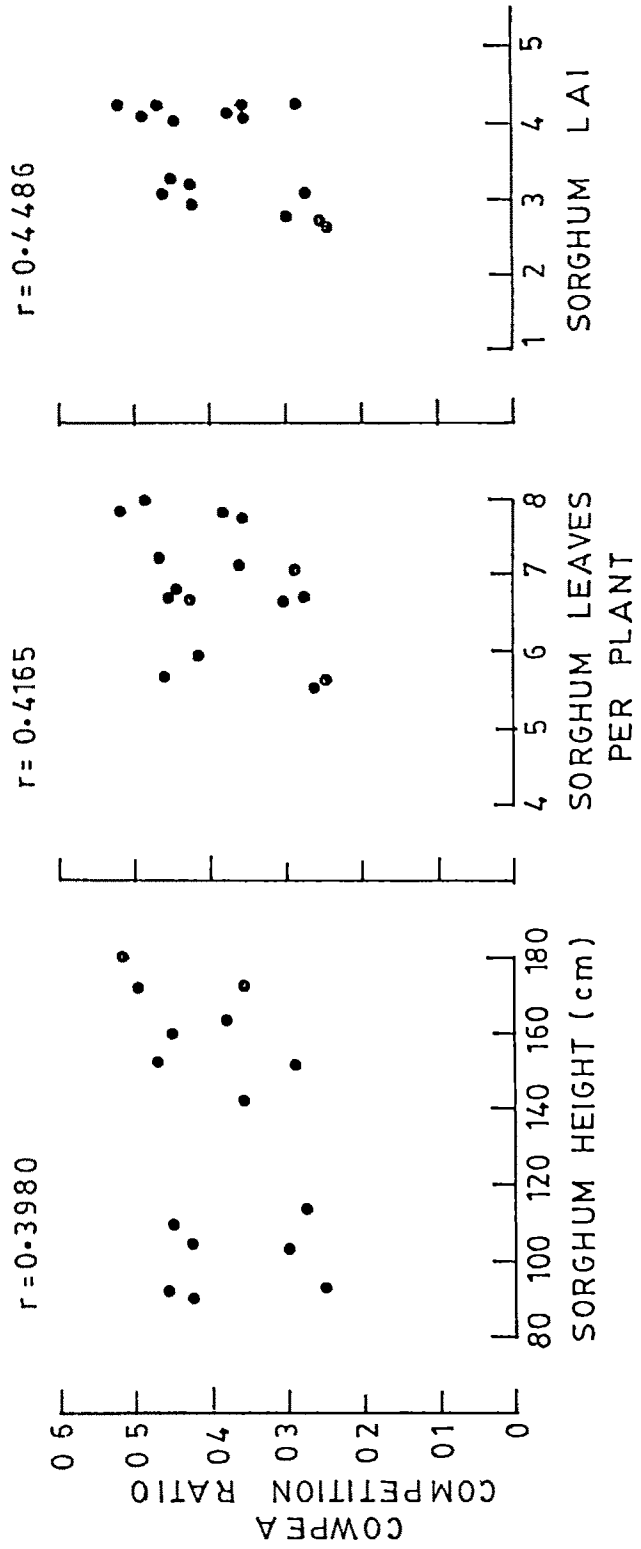
The correlation between the intercropped cowpea yield and sorghum growth characters was inconsistent. The weak negative correlation with sorghum height, leaves and leaf area index in the first year would suggest that light transmission was a limiting factor because these characters were related to light transmission through

sorghum canopy (Galwey et al., 1986). But in the second and third year, this relationship was positive implying that light transmission was not so important in this situation. Such lack of consistency in the effect of sorghum canopy characters on cowpea was reported by Galwey et al. (1986). Yet, the growth and yield of cowpea genotypes varied with the two sorghum genotypes. The lack of significance of the correlation between sorghum canopy characters and the competition ratio of cowpea (Fig. 5.6) indicated that this variation, henceforth, has to be explained only in terms of the effect of cowpea duration, the difference in duration between the two components and the overlap of critical phases of resources requirement between the two components.

c) Effect of duration of component crops on intercrop cowpea yield

The temporal difference in duration between the component crops has often been quoted as a major factor influencing the performance of the dominated crop in many intercrop situations (Willey and Rao, 1977; Chinnappan and Palaniappan, 1980; Singh, 1983; Palaniappan, 1985). For instance, in sorghum - pigeonpea intercropping, a longer duration difference was quoted as an advantage for getting higher yields from pigeonpea (ICRISAT, 1981). In this study, the yield of cowpea Co 1 was generally independent of the duration difference as evidenced by its nearly similar yields with both late and early sorghum genotypes. But cowpea Co 4 benefitted from an increase in duration difference between sorghum and cowpea. The yield of cowpea Co 4 was more with late sorghum than with early sorghum genotype.

FIG. 5.6 SORGHUM CANOPY CHARACTERS AND COWPEA COMPETITION RATIO



The apparent variation in the effect of duration difference on the two cowpea genotypes might be due to the difference in the overlap of critical periods of the two genotypes with sorghum. Cowpea Co 4 matured in 80-85 days and the sensitive period of early pod development and grain filling coincided with the critical period of flowering to early grain filling in the early maturing sorghum Co 22. This overlap of the critical phases of the two genotypes resulted in greater competition stress for cowpea from the dominant sorghum. Consequently, cowpea Co 4 yielded less with sorghum Co 22. The same cowpea genotype (Co 4) completed its critical stage of resource requirement before the commencement of the critical stage of the late maturing sorghum Co 25 and was able to yield relatively more with the late sorghum.

Since cowpea matured earlier than sorghum, there was overlap with sorghum throughout its growing period. This overlap caused a reduction in the rate of dry matter production by cowpea plants. This reduction in rate of DMP was probably compensated in cowpea Co 1 because of its long duration over which it was able to accumulate more DMP. In pigeonpea, the longer the duration available after sorghum harvest, greater was its ability to compensate the early reduction in dry matter production (Willey and Rao, 1981). Thus, the long duration cowpea Co 1 was able to yield more than the shorter duration genotypes Co 4 and CoVu 7. In other pulses like pigeonpea and lab lab, early maturing genotypes performed poorly in intercropping with sorghum (Madhavan et al., 1986; Anon., 1988).

The positive effect of longer duration of cowpea can also be interpreted in terms of the length of pod development period. It has been observed that more pods could develop on a plant provided the growth rate of individual pods was slower and extended to a longer period. This was required to enable the plant to cope up with the high demand for photosynthates during pod filling (Chaturvedi et al., 1980). Positive correlation between the length of reproductive phases and seed yield in cowpea was reported by Wien and Ackah (1978) and Uprety et al. (1979). In cowpea Co 1, the duration from flowering to harvest was longer (50-55 days) than in Co 4 (40-45 days) and CoVu 7 (35-40 days). The longer period of pod development in cowpea Co 1 thus enabled it to develop and sustain more pods leading to higher yields.

Thus, the effect of cowpea duration and the overlap of sensitive phases of growth between the two components proved to be more important than the duration difference per se in influencing the yield of intercropped cowpea.

5.2. Competition functions and their relationship to the competitive ability of the component crops

If each of the component crops in intercropping were to experience the same degree of competition as in sole cropping, then, the actual yield in intercropping ought to be equal to the 'expected' yield. Sorghum enjoyed the same degree of competition

in sole as well as intercropping as indicated by the nearness of actual yield to the expected yield. Introduction of cowpea as an intercrop caused little additional competition stress to sorghum. But in cowpea, the actual yield in intercropping, averaged over all intercrop combinations was only 42, 56 and 61 per cent of the expected yield respectively, in the three years, implying that the cowpea in intercropping experienced greater competition than in sole cropping.

For a given crop, if the relative crowding coefficient (RCC) was greater than, equal to, or less than unity, respectively, its intercrop yield would be greater than, equal to, or less than its expected yield (Willey and Rao, 1980). In this study, cowpea recorded RCC values less than one in all combinations and its actual yield was also less than expected in intercropping. In sorghum, however, the RCC was greater than unity, but the actual yield did not exceed the expected yield. The estimation of RCC considered the proportionate allotment of area to the components in replacement mixtures where the population of the components would be roughly proportional to the area allotted. But in the present study, an additive system was adopted and, though sorghum occupied only two-third of the area in intercropping, its population was kept constant in sole and intercropping by adjusting the crop geometry from solid row to paired row. In cowpea, the intercrop population was proportional to the one third area occupied by it. Since the constancy of sorghum population was not taken into account, there was the apparent

contradiction, as outlined earlier, in the interpretation of RCC to explain the competitiveness of sorghum.

A positive sign of the value of aggressivity for sorghum meant that sorghum was the dominant crop and cowpea, with negative values of aggressivity, was the dominated crop in sorghum-cowpea intercropping.

The range of competition ratio values for sorghum obtained in the study implied that sorghum was 1.9 to 3.8 times more competitive than cowpea. Correspondingly, the competitiveness of cowpea was reduced to only 0.26 to 0.51 times that of sorghum. This again confirmed the dominance of sorghum over cowpea in intercropping.

The values of the various competition functions described earlier and the actual yield of the component crops in various intercrop combinations exhibited only a weak correlation in the case of sorghum. But, all the indices, had a positive correlation with cowpea yield. It is therefore suggested that in additive intercropping systems, the competition functions such as relative crowding coefficient and aggressivity may be more useful to explain the competitiveness of the dominated component in intercropping situations.

5.3. Selection of genotypes of sorghum and cowpea for intercropping

Sorghum performance was similar in sole cropping and intercropping. Hence, genotype selection in sorghum for intercropping

can be done based on its sole crop performance itself. Sorghum genotype of medium duration (120-125 days) is suitable for normally distributed rainfall situations and an early maturing genotype (100 days) for end of season drought conditions. But, intercropped cowpea yield would be less with the early maturing sorghum genotype. Galwey et al. (1986) while analysing the genotypic variation in the response of sorghum to intercropping with cowpea, advocated that the sorghum genotypes selected for intercropping should not be dwarf types. Further, the requirement of high straw output in an animal oriented rainfed farming system, favours the choice of a late, tall sorghum. Based on these observations, it could be inferred that medium tall sorghum genotypes maturing in 120-125 days would offer more advantages in sorghum-cowpea intercropping.

The study enabled the identification of cowpea characters that were related to high yield in intercropping with sorghum. Thus, a cowpea genotype capable of high yield in sole crop, longer in duration (90-95 days) and exhibiting a taller canopy, more pod production, lesser grain test weight and high harvest index can be expected to yield high in intercropping with sorghum. The positive correlation for these characters in sole cropping and intercropping suggested that a preliminary screening of cowpea genotypes based on their sole crop performance with reference to the key aspects can be done to ascertain their suitability to intercropping. The selected genotypes have to be tested further in the actual intercrop situation itself to identify the most adapted genotype for the specific intercrop combination.

5.4. Soil moisture utilisation in sorghum-cowpea intercropping

5.4.1. Soil moisture availability and yield advantage

Soil moisture availability was higher throughout the crop growth period in 1984-85 as a result of the normal quantity of rainfall (563 mm) distributed uniformly in 25 rainy days. During 1985-86, the lower quantity (283 mm) and the early cessation of rainfall (at 67 DS) caused the soil moisture to recede below the wilting point after 80 DS. The higher total yield advantage in 1984-85 than in 1985-86 indicated that the intercrop advantage would be more under high moisture availability than under moisture stress conditions. Similar reports of improved intercrop performance under favourable moisture regimes/wet seasons were reported by Singh et al. (1978), Tomer and Saini (1979), Singh (1981), Singh (1985) and Hulugalle and Lal (1986). This suggested that water requirement under intercropping might be higher than sole crop. The water use estimated from effective rainfall and soil storage also indicated slightly greater removal of soil moisture in intercropping systems than by sole sorghum (Table 4.35).

5.4.2. Soil moisture depletion in sole sorghum and sorghum-cowpea intercropping

Available soil moisture content at every stage of estimation was lower in intercropping systems than in sole sorghum. This is indicative of a greater depletion of soil moisture through intercropping. The ability of the combined root systems of the two component crops

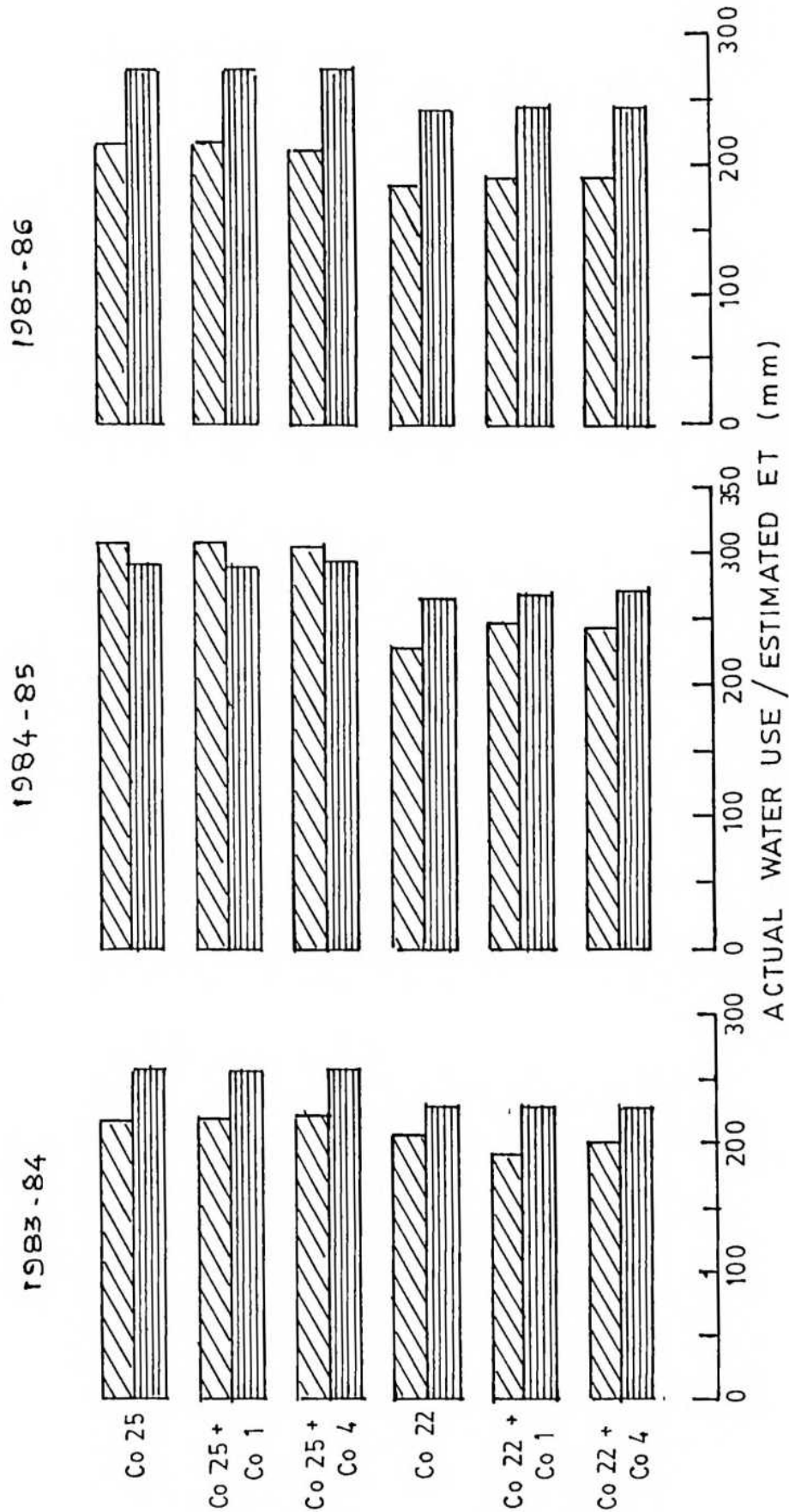
to exploit a greater volume of soil resulted in effective extraction of available soil moisture. The yield advantage in sorghum-cowpea intercropping was thus due to the mechanism of efficient use of available resource viz., soil moisture. Lower soil moisture content under sorghum-cowpea intercropping than sole sorghum was reported by Rees (1986).

5.4.3. Crop water requirement in sole sorghum and sorghum-cowpea intercropping

The actual crop water use was computed from soil moisture at sowing, effective rainfall during crop growth and soil moisture at harvest. This was compared with the crop evapotranspiration requirement estimated by Blaney and Criddle method (Doorenbos and Pruitt, 1975). The estimated crop evapotranspiration requirement varied from the actual water use by 10.3 to 40.3 mm under the different cropping systems (Fig. 5-7). The dependence of intercrop yield advantage on adequate soil moisture availability and high water requirement was reflected in high values of soil water use registered in intercropping systems. Higher water use efficiency of sorghum-cowpea intercropping under favourable moisture conditions was observed by Rees (1986).

The deviation between the estimated and actual crop water requirement could be due to certain assumptions made in the estimation of crop evapotranspiration. Crop coefficient (K_c) values were assumed to be similar for sole sorghum and sorghum-cowpea

FIG. 5-7 ESTIMATED EVAPOTRANSPIRATION (▨) AND ACTUAL WATER USE (▩) IN SOLE AND INTERCROPPING



intercropping. They were also assumed to be independent of soil moisture regime and rainfall distribution. The need for suitable adjustments in the crop coefficient values to suit cropping systems and soil moisture was also made clear from the comparison of estimated soil moisture balance and actual soil moisture content at various growth stages (Table 4.34).

The estimated balance and actual moisture content (Fig. 5.8, 5.9) showed a general agreement in the early stages upto 80 DS, especially in the normal rainfall year of 1984-85. Even here, the actual values for intercropping systems were lower than the estimate. As the soil moisture availability declined with crop growth or due to rainfall failure, the actual moisture content was higher than the estimated balance. This would suggest that actual evapotranspiration was probably lower than the estimated ET under low soil moisture regimes. The crop coefficient values used in the study were therefore more appropriate under conditions of unrestricted moisture availability. Yet, the attempted comparison established that with suitable crop coefficient values, the crop water requirement in intercropping could be predicted from weather parameters.

5.4.4. Soil moisture availability and yield of component crops in intercropping

Sorghum yield in intercropping was higher in 1984-85 than in 1985-86. The reduction in sorghum grain weight per ear during

FIG 5 8 TIME COURSE OF SOIL MOISTURE DEPLETION IN SOLE SORGHUM AND INTERCROPPING WITH COWPEA

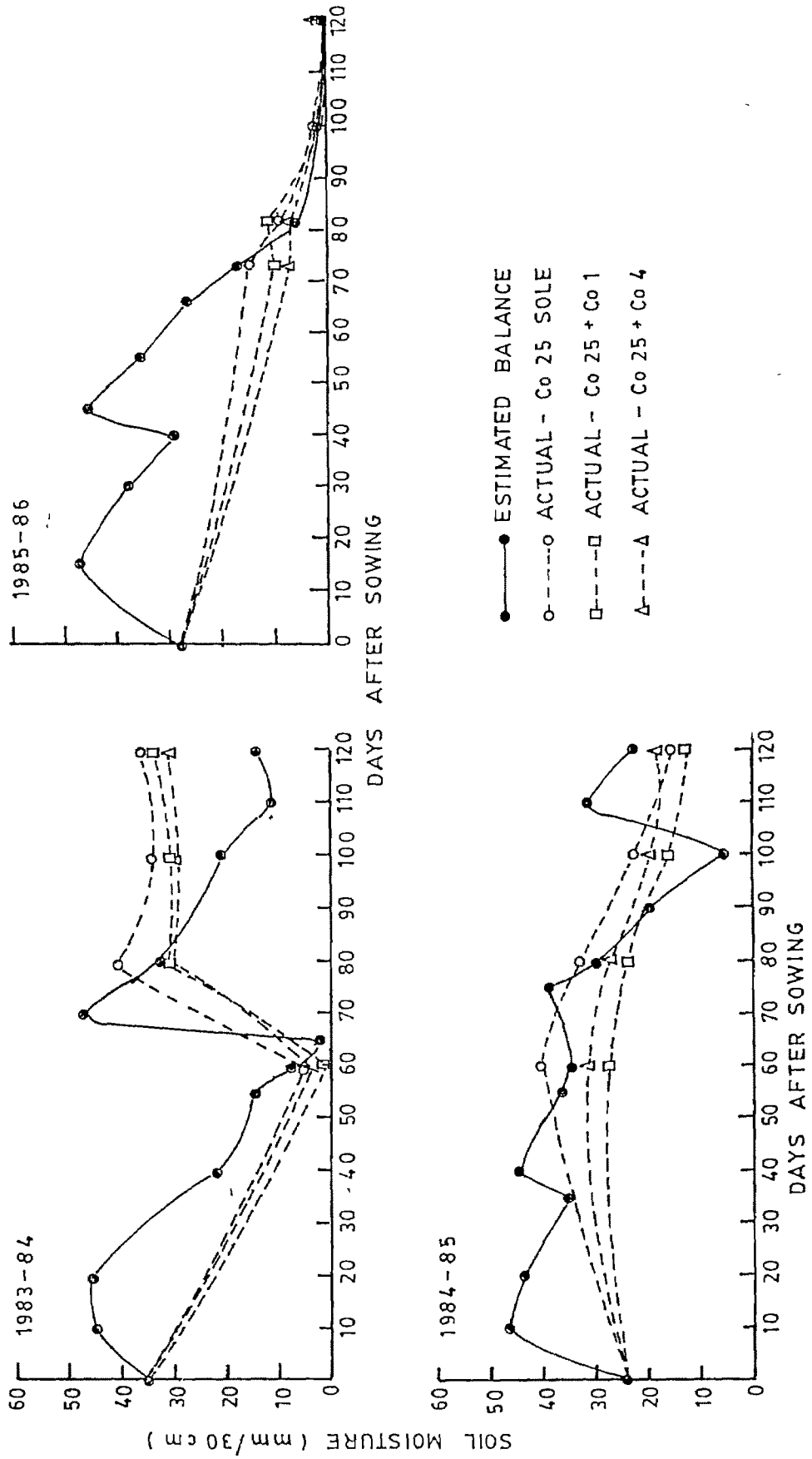
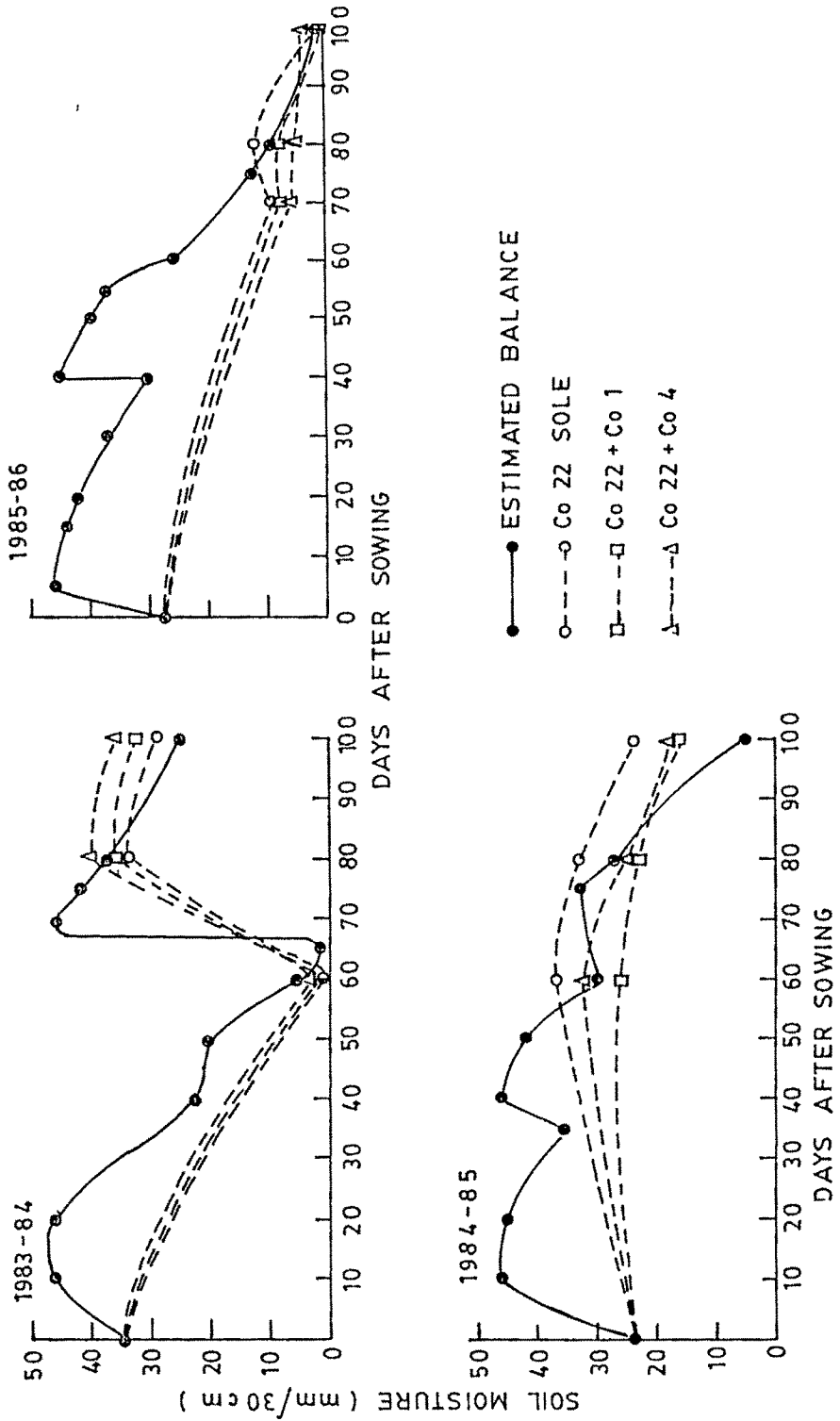


FIG. 5.9 TIME COURSE OF SOIL MOISTURE DEPLETION IN SOLE SORGHUM AND INTERCROPPING WITH COWPEA



1985-86 was caused by the low available moisture status after 60 DS. Moisture stress during flowering and grain filling affected grain setting and development, resulting in low yield. The effect of this moisture stress was more severe in the late maturing sorghum Co 25.

Cowpea yield in intercropping was also proportional to soil moisture availability. During 1983-84 and 1985-86, soil moisture content during the period from 60 to 80 DS coinciding with pod filling stage of cowpea was relatively lesser than in 1984-85. This was due to the occurrence of frequent dry spells during this period. This reduced availability of soil moisture at pod filling affected the grain yield of cowpea. Consequently, the contribution of cowpea to the total yield advantage of intercropping declined under the moisture stress conditions that prevailed during 1985-86. In a study on water relations of cowpea, Babalola (1980) observed higher reduction in yield when water stress was imposed at reproductive phase.

5.4.5. Land management practices and yield of component crops

Bed furrow sowing caused improvements in some of the growth characters of sorghum. Grain yield of sorghum was also increased in bed furrow sowing during 1984-85. Cowpea growth and yield was not affected by the land management practices. The potential benefits from bed furrow sowing as evidenced from other studies were attributed to reduced run-off (Venkateswarlu, 1986), an improvement in soil moisture storage (Chittaranjan et al., 1983) and easy drainage in heavy soils (ICRISAT, 1982).

Available soil moisture estimated at regular intervals during the crop growth showed only marginal difference between the two land shaping practices of flat bed sowing and bed-furrow sowing. In flat bed sowing, seeds were sown as such in the ploughed field without any land smoothening. This would have provided ample opportunity for depression storage in plough furrows similar to the effect caused by the regularly spaced furrows under bed furrow system. This probably resulted in the absence of any large difference in soil moisture storage between flat bed and bed furrow systems. Relatively high depression storage capacity of flat beds was helpful to permit a part of run-off water to get into the profile in studies at ICRISAT (1982).

In the absence of any significant improvement in moisture storage in bed furrows, the positive effect on sorghum yield observed during 1984-85 could only be due to an improvement in the general growth environment of sorghum sown in bed furrows. The prevention of water stagnation in the early growth stage could be a possible cause. In the first 50 days after sowing, run-off causing rainfall intensity occurred on 11 days during 1984-85 as compared to just 3 days in the corresponding period during 1985-86 (Appendix II). The excess rainfall during this early growth might be a reason why the sorghum growth parameters such as height and LAI at flowering were relatively lower in 1984-85 than in 1985-86. Under such circumstances, guided drainage through furrows in bed furrow system would have

proved to be more useful in controlling water stagnation. That such a benefit occurred was evident from the relatively lower soil moisture content in the surface layer in bed furrow than in flat bed. Soil moisture content in the surface 15 cm layer was consistently lesser in bed furrow than in flat bed (Table 4.33) especially during the early stage (60 DS) when the rainfall intensity was high enough to cause stagnation and run-off. Better drainage through bed furrow system caused the surface soil to be more friable at this stage.

The advantage of bed furrow sowing in this study was realised through guided run-off rather than improved soil moisture availability. Sharma et al. (1982) attributed the benefit of bed furrow system to a better growth environment in general even when soil moisture storage was not increased. The absence of any difference in soil moisture content between flat bed sowing and bed furrow sowing might also explain the non-significance of the interaction between land management practices and nitrogen application.

5.5. Nitrogen application and the growth and yield of component crops in intercropping

Management of fertilizer nitrogen has been shown to play an important role in the complementarity of intercropping (Wijesinha et al., 1982). It acquires more significance when the intercrop is a legume. Apart from an anticipated enhancement of nutrient requirement by the combined population in intercropping (Natarajan and Willey,

1980), the "legume effect" in contributing fixed nitrogen to the non-legume is often quoted as a factor influencing fertilizer nitrogen supply to intercropping with legumes. (Narain *et al.*, 1980; Snaydon and Harris, 1981). There is also the possibility of differential response of crop species to applied nitrogen in sole and intercropping (Wahua, 1983; Ofori and Stern, 1987), necessitating an increase or saving in fertilizer nitrogen in intercropping systems. The results from this study were analysed with this background.

5.5.1. Response of sorghum to nitrogen application in sole cropping and intercropping

Sorghum responded positively to applied N in both sole and intercropping. Significant yield gains in sorghum at 20 and 40 kg N levels were registered in sole cropping as well as intercropping through an improvement in earlength and grain weight per ear. The yield increase due to nitrogen application continued at the higher level of 40 kg N also, as found in early studies (Ahuja and Singh, 1987). The difference between 20 and 40 kg levels could also be due to the effect of split application done with 40 kg level (Rao and Das, 1982; Kanwar *et al.*, 1984).

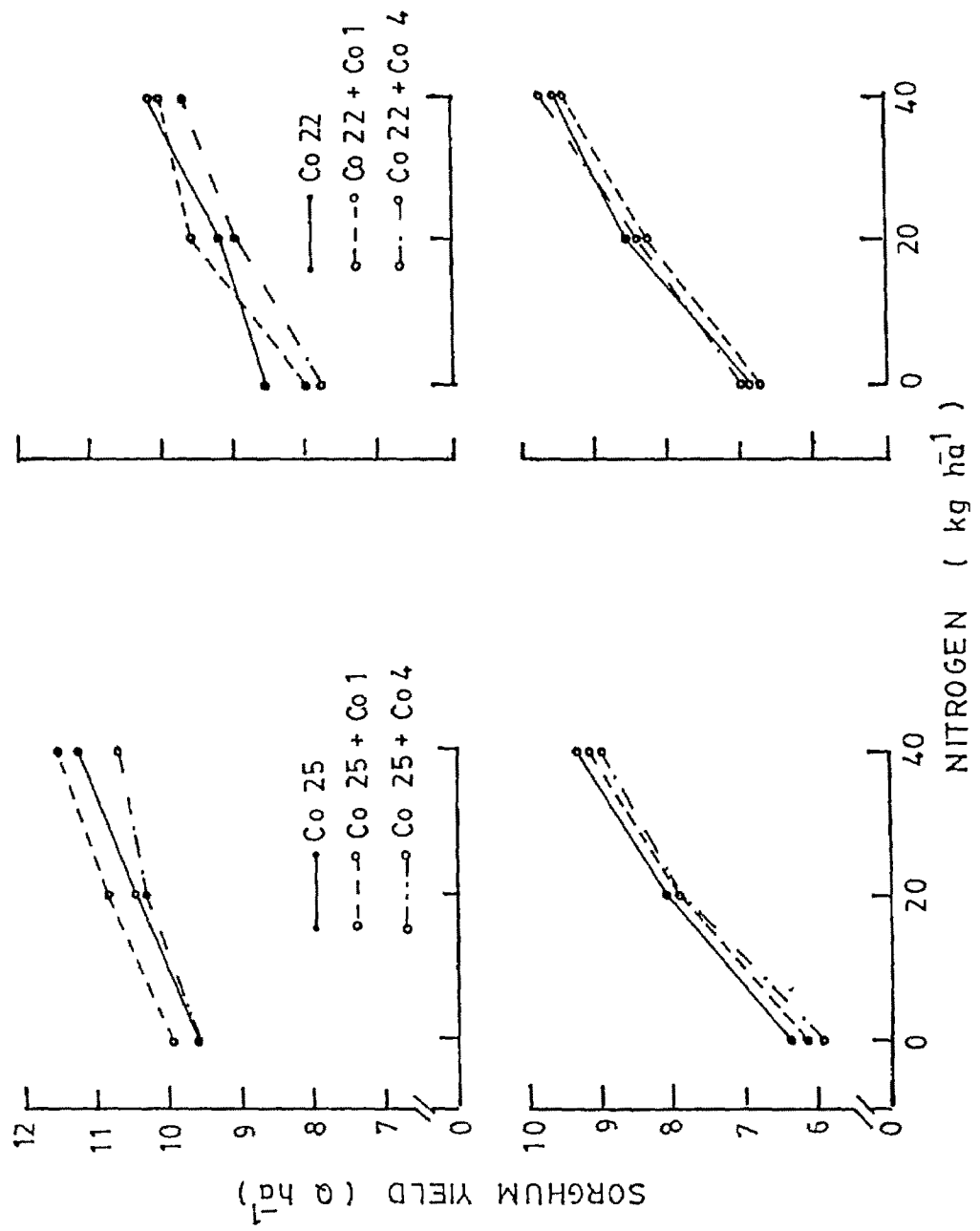
An important aspect of concern as already focussed is whether sorghum response to nitrogen would vary between sole cropping and intercropping. Significant gain in sorghum yield was recorded with nitrogen application in sole sorghum as well as intercropping

systems in this study. And, the response of sorghum to applied nitrogen was independent of the cropping system as indicated by the lack of significance of the interaction between nitrogen application and cropping systems. The uptake of nitrogen by sorghum at any N level was of similar magnitude in sole cropping as well as intercropping. In other words, sorghum responded similarly to nitrogen application in both sole cropping and intercropping with cowpea. Similar results have been reported by Rao (1985) and Rao *et al.* (1987).

5.5.2. Legume effect

The progressive increase in sorghum yield in intercropping with every increment of N suggests that there was no contribution of fixed nitrogen from cowpea to sorghum. An yield increase in intercropped sorghum over sole sorghum at zero nitrogen level would have been a potential proof of the legume effect. But, here, sole sorghum yields, especially in sorghum Co 22, were slightly reduced at zero nitrogen level in 1984-85, suggesting only a possible competition for available soil N from cowpea (Fig.5.10). With nitrogen application, this competition was removed and intercropped sorghum produced a slightly higher response at 20 kg N level. This dispelled the possibility of any nitrogen contribution from cowpea to sorghum. Lower yield of intercropped sorghum due to competition from intercrop has been reported by Ahuja and Singh (1987). Competition for N between cowpea and maize was observed by Ofori and Stern (1987).

FIG. 5-10 SORGHUM GRAIN YIELD WITH NITROGEN LEVELS IN SOLE AND INTERCROPPING



The legume effect in intercropping has always been a debated point. The possibility of fixed nitrogen from legumes being made available to the associated nonlegumes in intercropping depends on many factors such as the extent of fixation of N by the legume and the time of release of fixed N for any possible use by the nonlegume. With a low plant density and much reduced growth, the intercropped cowpea could not have fixed more N because the energy intensive process of N fixation would require large amount of net photosynthates. Reduction in the plant vigour and nodulation of the intercrop legume due to shading by sorghum or under artificial shading was found to result in poor biological N fixation (Dart, 1979; Eriksen and Whitney, 1984; Waghmare and Singh, 1984). All the cowpea genotypes evaluated in this study recorded considerable reduction in growth vigour and dry matter accumulation. This might have affected nitrogen fixation and potential transfer to sorghum. In many legume-nonlegume intercropping studies, the absence of legume effect was reported (Rego, 1981; Searle et al., 1981; Umat and Deshpande, 1985; Rao et al., 1987).

5.5.3. Cowpea yield with nitrogen application

The response of intercropped cowpea to applied nitrogen was inconsistent over the two years. This could be related to the moisture availability between the seasons. During 1984-85, when rainfall quantity and distribution was normal, and the soil moisture availability was adequate throughout the cropping period, the competition for moisture between sorghum and cowpea would have been relatively

lesser. This enabled cowpea to give higher yield with nitrogen application. Even here, the response did not increase beyond 20 kg N. During 1985-86, soil moisture availability was at a reduced level and this would have affected cowpea growth and its response to added nitrogen. Choudhury and Misanger (1981) reported that when competition for moisture was aggravated, chickpea intercropped with sorghum did not respond to increased nutrient availability.

5.5.4. Total nitrogen uptake in sole sorghum and sorghum-cowpea intercropping

An increase in total uptake of nitrogen in intercropping over sole sorghum was seen during 1984-85 only. Nitrogen uptake by sorghum remained similar between sole sorghum and intercropped sorghum in the two years. So, the possible cause of greater total uptake of N during 1984-85 alone could be due to a greater DMP by cowpea under adequate soil moisture availability and a consequent higher nitrogen uptake. Under the limited soil moisture availability during 1985-86, dry matter production by cowpea was comparatively lesser and therefore nitrogen uptake by cowpea was also reduced. This resulted in nitrogen uptake being similar in sole sorghum and intercropping systems.

5.5.5. Fertilizer nitrogen requirement of sorghum-cowpea intercropping

The continued response of sorghum in intercropping to the higher level of 40 kg N implies that, to maintain higher productivity

of sorghum in intercropping, application of 40 kg N is essential and there is little scope of reducing fertilizer nitrogen level for intercropping situations. This is confirmed by the high total yield advantage at 40 kg level (LER = 1.26-1.36) over 20 kg level (LER = 1.21-1.22).

5.6. Complimentary aspects of sorghum-cowpea intercropping

5.6.1. Weed control in intercropping

The significant reduction in weed dry matter under sorghum-cowpea intercropping system compared to sole sorghum or sole cowpea adds evidence to the extensively reported view that weed suppression is one of the mechanisms of intercropping advantages (Gangwar, 1986; Venkateswarlu and Ahlawat, 1986). As observed by Moody (1978), the competitive ability of the component crops in intercropping against the weeds was enhanced by the high plant population pressure provided by the component species together leading to greater weed suppression. Another observation by Moody (1978) that differences existed between sorghum cultivars in weed control ability was also evident in this study. The lesser weed dry weight in sorghum Co 25 based cropping systems than in sorghum Co 22 based cropping systems was due to the faster rate of early growth of the tall sorghum Co 25 exerting more competitive pressure on weeds. Rao and Shetty (1976) attributed the quick early growth of maize as the cause of its initial weed smothering ability as compared to other millets. With a spreading habit, cowpea Co 4 as sole crop, naturally caused greater weed suppression than the tall climbing cowpea Co 1 or the erect genotype CoVu 7.

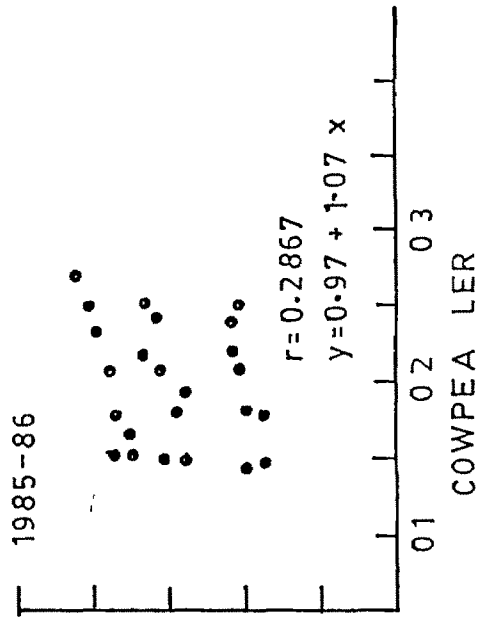
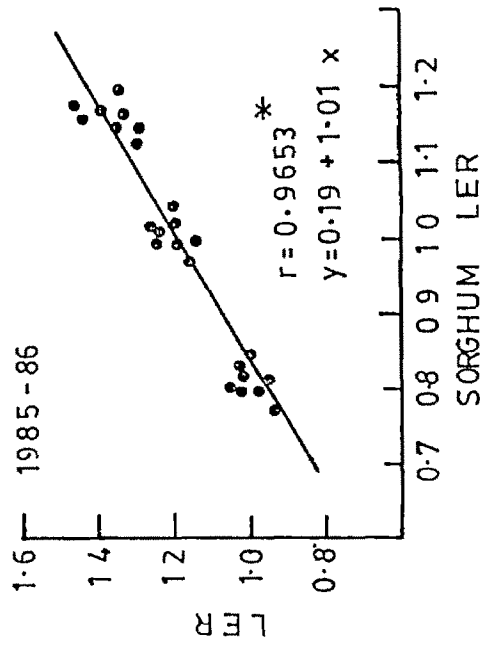
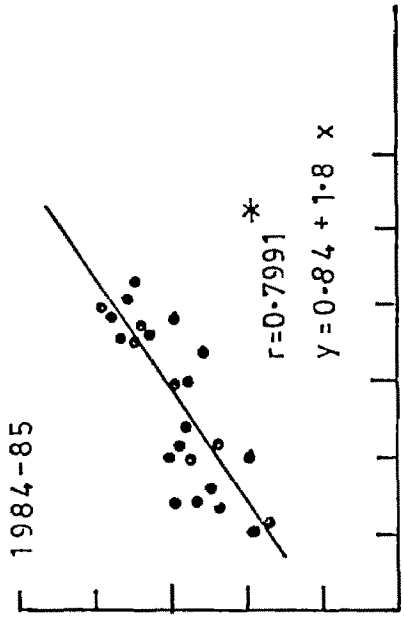
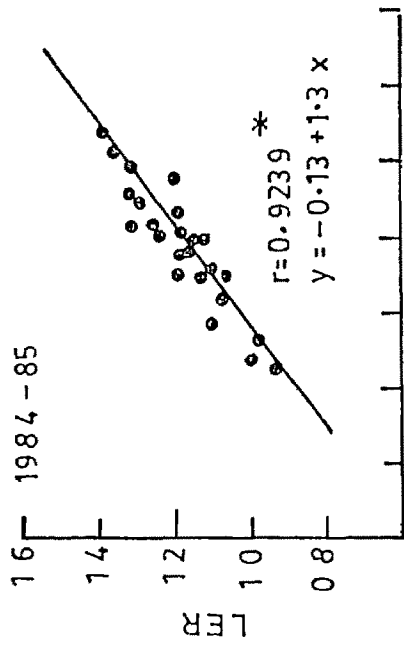
5.6.2. Yield advantage of sorghum-cowpea intercropping

Yield advantage in intercropping is indicated by higher total productivity over the sole crop of the component species. It was measured in terms of the land equivalent ratio in this study. Averaged over all the combinations of genotypes of sorghum and cowpea, the yield advantage in sorghum-cowpea intercropping was 18 per cent (LER = 1.18) in the wet year and 19 per cent (LER = 1.19) in the dry year. This again lends credence to the compatibility of sorghum and cowpea for intercropping under varying conditions of rainfall quantity and distribution.

But the relative contribution of the two component crops to the total yield advantage of the intercropping system varied with rainfall quantity and distribution. Sorghum LER was uniformly high in both the years and its correlation with LER of the system was also highly significant in the wet ($r = 0.9239$) as well as the dry ($r = 0.9760$) years (Fig. 5.11). The lower value of 'a' in the regression of sorghum LER on the LER of intercropping system is an indication of the greater dependence of intercrop yield advantage on sorghum contribution. It is also a measure of the greater competitiveness and dominance of sorghum in the intercrop situations under varying conditions of moisture availability.

Though the cowpea LER was nearly constant for individual genotypes during both years, the contribution of cowpea to total yield

FIG. 5 11 REGRESSION OF COMPONENT CROP LER ON SYSTEM LER



advantage of intercropping was less significant in the drier year ($r = 0.2867$) than in the wet year ($r = 0.7991$) (Fig. 5.11). The contribution of the less competitive, dominated cowpea to yield advantage declined with reduction in moisture availability.

The large variation in the LER of the various combinations of genotypes is a proof of the importance of the choice of genotypes of the component crops as a suitable agronomic manipulation to improve yield advantage of the intercropping system. This is true especially for the dominated component. It was the cowpea genotype that was more responsible for the variation than the sorghum genotype. With any sorghum genotype, the late maturing climbing cowpea Co 1 resulted in larger yield advantage than the early maturing, spreading cowpea Co 4. In the choice of genotypes for intercropping, more attention is, therefore, needed for the dominated cowpea. This also brings out the need to manage cowpea carefully in intercropping to derive more benefits as pointed out by Spitters (1983) and Ofori and Stern (1987).

Although the values of LER of intercropping systems were nearly similar between the years, the absolute yield was higher during the wet year than the dry year. This difference in interpretation on the basis of LER and absolute yield brings out the limitation of the concept of LER. At the most, LER could be construed as an index of the relative physiological efficiency of intercropping compared to sole crop

(Willey, 1979a) and it has to be interpreted along with absolute yield also to derive meaningful conclusions for practical use.

In the absence of any great increase in the absolute yield of crops caused by a change in land management practices, the cause of the increase in LER under bed furrow sowing is uncertain. This again points to the caution needed in interpreting yield advantage of intercropping systems based on LER only.

The total yield advantage of sorghum-cowpea intercropping was considerably improved by nitrogen application in the wet as well as dry years. This agrees with the results obtained in earlier studies, (Rego, 1981; Ahuja and Singh, 1987). The decrease in the biological advantage of intercropping with nitrogen application as observed in some studies (Rao and Willey, 1981; ICRISAT, 1982) was attributed to a possible suppression of legume growth by applied nitrogen. In this study, however, cowpea growth and yield were either enhanced or not affected by nitrogen application. With an increase in the yield of the other component, sorghum, the LER of intercropping was therefore, enhanced with nitrogen application. This highlights the need to supply adequate nitrogen to augment the yield advantage from rainfed sorghum-cowpea intercropping.

5.6.3. Yield stability in intercropping

Stability in yield is a major reason why intercropping is more common in drylands. The belief that intercropping is a

biological insurance against risk of complete crop failure in rainfed farming came true in the first year of this study. Unusually heavy and continuous rainfall during the flowering stage of sorghum resulted in zero grain yield from sorghum. While this led to complete crop loss in sole sorghum, the intercropping systems returned some quantity of cowpea grain atleast. Again, the yield of sorghum Co 25 fluctuated greatly between the second and third year because of erratic distribution of rainfall in the later year. Yet, the total yield advantage (LER) in sorghum Co 25 based intercropping systems was maintained at the same level in both the years, confirming the stabilising effect of intercropping systems. This is a good reflection of the dryland farmers' wisdom in their cropping decision.

5.6.4. Total dry fodder yield and quality in intercropping

Apart from the total grain yield advantage in intercropping the improved quality of the total dry fodder in terms of crude protein content was another advantage of sorghum-cowpea intercropping. The quantity of total dry fodder made up of sorghum straw and cowpea haulms was much the same as sole sorghum straw yield. This was so because the lower plant density and reduced growth vigour of intercropped cowpea allowed only a smaller yield of cowpea haulms. But, the higher nitrogen content of cowpea haulms helped to increase the crude protein content of the mixed fodder from intercropping over that of sole sorghum straw. This aspect is of significance in dryland farming systems where integration of crop and livestock husbandry is widely practised.

5.6.5. High income and income stability in sorghum-cowpea intercropping

The high income potential of intercropping system over sole sorghum justified the suitability of sorghum-cowpea intercropping as a means of increasing the net returns from rainfed cropping. The additional expenditure on cowpea in intercropping system was minimal (Rs.95 ha⁻¹). Coupled with the high unit price of cowpea grain, this enhanced the cost-benefit ratio of sorghum-cowpea intercropping over sole sorghum.

Among the many genotype combinations, sorghum Co 25 with cowpea Co 1 proved to be the most remunerative association. This was made possible through the high grain and straw yield of sorghum Co 25 and the high grain yield of cowpea Co 1. The ability of cowpea Co 1 to be more competitive and yield high in intercropping with sorghum was reflected in the higher income from the intercropping systems with cowpea Co 1 than with cowpea Co 4.

Apart from the actual increase in income, the stability of income was also apparent in the intercrop situations. In spite of the deviations in rainfall quantity and distribution, the returns from sorghum-cowpea intercropping were consistently higher than from sole sorghum. Even when the sorghum yield was completely lost due to aberrant rainfall, the loss was minimised in intercropping systems.

The additional returns and high cost benefit ratio achieved through nitrogen application justified the additional investment on fertilizer nitrogen for intercropping systems and also emphasised the need for proper nitrogen management in rainfed sorghum-cowpea intercropping.

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

Field experiments on sorghum-cowpea intercropping under dryland situations of semi-arid tropics (SAT) were conducted at Tamil Nadu Agricultural University, Coimbatore during 1983-86. Evaluation of the compatibility of genotypes of sorghum and cowpea for intercropping and the effect of land management practices and nitrogen application on the performance of sorghum-cowpea intercropping formed the objectives of the study.

Two sorghum genotypes differing in duration and height, viz. tall, 125 days sorghum Co 25 and dwarf, early (100 days) sorghum Co 22 were intercropped with three cowpea genotypes viz., 90-100 days climbing cowpea Co 1, 80-85 days spreading cowpea Co 4 and 70-75 days erect cowpea CoVu 7. Land management practice of bed furrow sowing was compared with flat bed sowing. Nitrogen levels tried were 0, 20 and 40 kg ha⁻¹. The experiment was laid out in factorial randomised block design in the first year and in split plot design in the second and third year.

Observations were made on the growth characters, yield attributes and yield of grain and straw/haulms of the component crops. Total yield advantage and monetary returns were estimated. Soil moisture balance and crop evapotranspiration were computed and compared with actual soil moisture utilisation in different intercrop combinations.

Nitrogen uptake by the component crops was estimated. The competitive ability of the genotypes of component crops was evaluated through competition functions. The results and conclusions from the study are summarised here.

Summary of results

The growth characters and yield attributes of sorghum genotypes were unaffected by intercropping with cowpea genotypes differing in duration and plant type. The grain yield of intercropped sorghum was 95-103 per cent of sole sorghum. Variation in rainfall quantity and distribution resulted in yield differences between sorghum genotypes. With normal rainfall of above 400 mm distributed in 25 rainy days uniformly, the late tall sorghum yielded more than the early dwarf sorghum. Early cessation of rainfall caused severe reduction in the grain yield of late maturing sorghum genotype.

Sorghum yield was higher in bed furrow sowing than in flat bed through guided drainage in seed bed when high intensity rainfall occurred in early season. In low rainfall year, this advantage was not manifested.

Sorghum yield increased with nitrogen application in sole cropping as well as intercropping. Sorghum yield in intercropping with applied nitrogen was comparable with sole sorghum yield. Application of 40 kg N ha⁻¹ was more effective than 20 kg N ha⁻¹ in both sole cropping and intercropping.

Sorghum affected the growth of cowpea in intercropping. Grain yield of intercropped cowpea ranged from 10 to 25 percent of sole crop yield. The low yield of intercropped cowpea is attributed to lesser plant density (33 percent of sole crop) and the effect of competition from sorghum.

Distinct differences in intercrop yield were seen among cowpea genotypes. The climbing cowpea Co 1 maturing in 90-100 days gave consistently higher yields than 80-85 days spreading cowpea Co 4 and 70-75 days erect cowpea CoVu 7. Longer duration, tall canopy, larger specific leaf area, more pods per plant, high harvest index and greater remobilisation of photosynthates from vegetative to reproductive parts contributed to the higher yield of Co 1 cowpea in intercropping.

The grain yield of cowpea in intercropping was higher with tall late sorghum than with early dwarf sorghum. The overlap of critical stages of resource requirement viz. flowering to early grain filling in sorghum and early pod filling in cowpea, aggravated the competition stress for moisture in cowpea and reduced its yield in association with early sorghum.

Intercropped cowpea yield did not vary much due to sowing in flat bed or bed furrow. Under adequate soil moisture availability caused by normal rainfall, intercropped cowpea responded

to applied nitrogen. When soil moisture became limiting due to low rainfall, cowpea yield was not influenced by nitrogen applied to intercropping system.

Sorghum was dominant and more competitive than cowpea in intercropping systems as indicated by competition functions such as relative crowding coefficient, aggressivity and competition ratio.

Total yield advantage of sorghum-cowpea intercropping was higher by 8 to 27 percent over sole sorghum (LER = 1.08-1.27). The yield advantage of sorghum-cowpea intercropping was more dependent on sorghum yield than cowpea yield. Contribution of cowpea to yield advantage of intercropping was reduced under moisture stress conditions, at early pod filling. The combination of tall, 125 days sorghum Co 25 with 90-100 days climbing cowpea Co 1 resulted in higher LER (1.24 to 1.27) than other combinations of genotypes of sorghum and cowpea.

Net monetary returns and cost-benefit were consistently higher in sorghum-cowpea intercropping than sole sorghum under varying conditions of rainfall quantity and distribution. The income stability by intercropping was evident from the compensatory effect of cowpea yield, though to a lesser extent, when no sorghum yield was possible due to continuous rains at flowering.

Other benefits of sorghum-cowpea intercropping included the greater suppression of weed growth over sole sorghum. Genotypic differences in weed control ability of intercropping systems were indicated by lesser weed growth in tall sorghum based intercropping systems than in dwarf sorghum based intercropping systems.

Total yield advantage of intercropping marginally increased in bed furrow sowing (LER = 1.19-1.20) over flat bed sowing (LER = 1.16-1.18). Soil moisture content did not vary much between the two land management practices. The advantage under bed furrow sowing was probably due to the facility of guided drainage and prevention of water stagnation in the early rainy season.

Lower soil moisture content at various growth stages under intercrop treatments indicated greater depletion of soil moisture by sorghum-cowpea intercropping than sole sorghum. The crop water use by sorghum-cowpea intercropping estimated from soil moisture content and effective rainfall ranged from 190 to 309 mm in the different seasons and was slightly higher by 4 to 18 mm over sole sorghum. Soil moisture balance estimated from crop evapotranspiration and rainfall showed a general agreement with the actual soil moisture content in the early stages of crop growth, when soil moisture was not a constraint.

Nitrogen application enhanced the yield advantage of sorghum-cowpea intercropping substantially (LER = 1.21-1.36) over

no nitrogen (LER = 1.01-1.06). The continued response of intercropped sorghum to every increment in added nitrogen suggested that there was little contribution of fixed nitrogen from cowpea to sorghum.

The non-significance of the correlation between sorghum canopy characters such as height, leaves and LAI with intercrop cowpea yield suggested that light transmission was less limiting than competition for moisture or nutrients. Correlations studies enabled the identification of cowpea growth characters contributing to higher yield in intercropping.

Conclusions

Sorghum and cowpea are compatible for intercropping under dryland conditions. Higher productivity and monetary returns per unit area per unit time and income stability could be achieved through sorghum-cowpea intercropping. Differences in duration and plant type of cowpea genotypes would not affect sorghum yield in intercropping.

Tall, late maturing (125 days) sorghum genotype would be preferable for intercropping with cowpea than dwarf early sorghum because of high yielding ability, more straw yield and lesser adverse effect on growth and yield of component cowpea. Cowpea genotypes of long duration (90-100 days) with tall canopy, larger specific leaf area, more pod production, smaller grains and high harvest index would be advantageous in intercropping with sorghum. The combination

of late maturing (125 days) tall sorghum with long duration (90-100 days) climbing cowpea would be better than other combinations of late tall sorghum or early dwarf sorghum with spreading or erect cowpea genotypes of 70-80 days duration.

The advantages of sorghum-cowpea intercropping in drylands would be higher under conditions of adequate soil moisture availability. It is preferable to adopt bed furrow system for sorghum-cowpea intercropping system when rainfall of high intensity in early rainy season is anticipated. The yield and monetary advantages of rainfed sorghum-cowpea intercropping could be considerably enhanced by the application of nitrogen as required for sole sorghum.

An integrated management system for sorghum-cowpea intercropping in drylands would involve the combination of late tall sorghum genotype with long duration climbing cowpea genotypes, sowing in bed furrow and the application of 40 kg N ha⁻¹.

Further research need

Preliminary screening of cowpea genotypes for their adaptability to intercropping can be done based on high yield potential in sole crop. Further evaluation to select adapted genotypes has to be done in actual intercrop situation.

Optimisation of population of intercrop cowpea with reference to genotype may help to increase total yield advantage of intercropping. Plant density, genotype interactions in cowpea and other legumes deserve detailed investigations to promote intercropping advantages.

REFERENCES

REFERENCES

- Abraham, C.T. and S.P. Singh. 1984. Weed management in sorghum legume intercropping system. *J. agric. Sci., Camb.*, 103: 103-115.
- Adetiloye, P.O. 1980. Growth, development and yield in sole and intercropped cowpea and maize. *Cowpeas - Abstract of World Literature*, IITA, Ibadan, Nigeria p.134.
- Agboola, A.A. and A.A. Fayemi, 1972. Fixation and excretion of N by tropical legumes. *Agron. J.*, 64 : 409-412.
- Ahmed, S. and H.P.M. Gunasena. 1979. N-utilistion and economics of some intercropped systems in tropical countries. *Trop. Agric.*, 56(2) : 115-123.
- Ahmed, S., M. Sadik and L. Kobayashi. 1976. Studies on intercropping with grain legumes - a review. *Cowpeas - Abstract of World Literature*, IITA, Ibadan, Nigeria. p. 135.
- Ahuja, K.N. and S.P. Singh. 1987. Response of sorghum legume intercropping system to nitrogen and phosphorus in dryland conditions. *Indian J. Agron.* 32(3) : 245-249.
- Allen, J.R. and R.K. Obura. 1983. Yield of corn, cowpea and soybean under different intercropping systems. *Agron. J.* 75(6): 186.
- Andrews, D.J., 1974. Response of sorghum varieties to intercropping. *Expt. Agric.*, 10 : 57-63.
- Anonymous. 1982. Sorghum Research in Tamil Nadu. *Ann. Rep.* 1981-82, School of Genetics, TNAU., Coimbatore, India, p.63-77.

- Anonymous. 1988. Evaluation of lab lab genotypes for intercropping with rainfed sorghum. Research project completion report, Regional Research Station, Paiyur, TNAU., Coimbatore, India.
- Babalola, O. 1980. Water relations of three cowpea cultivars. *Plant and Soil*. 50 : 59-69.
- Baker, E.F.I. 1981. Population, time and crop mixtures. Proc. International Workshop on intercropping, Jan 1979, ICRISAT, Hyderabad, India. p. 52-62.
- Baker, E.F.I. and D.W. Norman. 1975. Cropping systems in Northern Nigeria. Proc. cropping systems workshop, IRRI, Los Banos, Philippines, 1975. p. 334-361.
- Baker, E.F.I. and Y. Yusuf. 1976. Research with mixed crops at the Institute for Agricultural Research. Proc. Symposium on intercropping in semiarid areas, May, 1976, Morogora, Tanzania.
- Balasubramanian, V. 1983. Pulses and oilseeds in rainfed cropping systems. In: *Dryland Agricultural Research in India - Thrust in the Eighties*, AICRPDA, Hyderabad, India. 1983. p.25-41.
- Balyan, J.S. and J. Seth. 1985. Effect of pure and intercropped stands of maize and cowpea on succeeding wheat. *Indian J. Agron.*, 30(2): 177-180.
- Bantilan, R.T. and R.R. Harwood. 1974. The influence of intercropping corn with mungbean and cowpea on the control of weeds. *Cowpeas - Abstract of World Literature*, IITA, Ibadan, Nigeria, p. 221.

- Bantilan, R.T., M.C. Palada and R.R. Harwood. 1974. Integrated weed management - key factors affecting crop-weed balance. *Phil. Weed Sci. Bull.*, 1(2) : 14-36.
- Bede, N. Okigbo. 1981. Evaluation of plant interactions and productivity in complex mixtures. *Proc. International Workshop on Intercropping*, Jan. 1979, ICRISAT, Hyderabad, India. p. 155-179.
- Blackman, G.E. 1956. Influence of temperature and light on leaf growth. In: *The growth of leaves* (Ed) F.L. Milthorpe, Butterworth, London, pp. 151-169.
- Boopathi Babu, D., 1978. Studies on weed control in sorghum based intercropping systems. M.Sc.(Ag.) dissertation, Dept. of Agronomy, TNAU., Coimbatore, India.
- Breese, E.L. and J. Hill, 1973. Regression analysis of interaction between competing species. *Heredity*, 31: 181-200.
- Chandrababu, R., R. Sadasivam, N. Natarajaratnam and S.R. Sree Rangaswamy, 1985. Photosynthesis in relation to yield potential in blackgram. *Madras agric. J.*, 72(3): 152-155.
- Chaturvedi, G.S., P.K. Aggarwal and S.K. Sinha. 1980. Growth and yield of determinate and indeterminate cowpea in dryland agriculture. *J. agric. Sci.*, 94(1): 137-144.
- Chauhan, G.S. and R.K. Joshi. 1980. Path analysis in cowpea. *Trop. grain legume Bull.* 20 : 5-7.
- Chinnappan, K. and SP. Palaniappan. 1980. Multitier cropping in castor. *Indian J. agric. Sci.*, 50: 342-345.

- Chittaranjan, S., U.S. Patnaik and M.S. Ramamohan Rao. 1983. Broad beds conserve more moisture and increase yields of jowar in black soils. Soil conservation Newsletter, 2(1): 7.
- Choudhury, M.S. and R.N. Misanger. 1981. Sorghum-chickpea intercropping trial in Morogoro, Tanzania. Proc. International Workshop on Intercropping, Jan. 1979, ICRISAT, Hyderabad, India, p. 217-221.
- Choudhury, S.L., 1981. Recent studies in intercropping systems on the drylands of India - some thoughts, some results. Proc. International Workshop on intercropping, Jan. 1979, ICRISAT, Hyderabad, India. p. 299-305.
- Christie, P., E.I. Newman and R. Campbell. 1974. Grass land species can influence the abundance of microbes on each other's roots. Nature, 250 : 570-571.
- Crookston, R.K. and R. Kent. 1976. Intercropping - a new version of an old idea. Crops and soils, 28(9) : 7-9.
- Dalal, R.C., 1974. Effects of intercropping maize with pigeonpea on grain yield and nutrient uptake. Expl. Agric. 10 : 219-224.
- Dart, P.J., 1979. N-fixation in intercropping. Proc. International Workshop on intercropping, Jan. 1979, ICRISAT, Hyderabad, India.
- De, R., R.S. Gupta, S.P. Singh, M.Pal, S.N. Singh, R.N. Sharma and S.K. Kaushik, 1978. Interplanting maize, sorghum and pearl millet with short duration grain legumes. Indian J. agric. Sci., 48(3) : 132-140.

Donald, C.M. 1963. Competition among crop and pasture plants. Adv. Agron., 15 : 1-118.

Doorenbos, J. and W.O. Pruitt. 1975. Crop water requirements. FAO Irrigation and drainage paper 24, Rome, Italy.

Eriksen, F.J. and A.S. Whitney, 1984. Effects of solar radiation regimes on growth and N-fixation of soybean, cowpea and bushbean. Agron. J., 76: 529-535.

Faris, M.A., H.A. Burity, O.V. Dosreis and R.C. Mafra. 1983. Intercropping of sorghum or maize with cowpeas or common beans under two fertility regimes in Northern Brazil. Expl. Agric., 9(3) : 251-261.

Fawusi, M.O.A., S.B.C. Wanki and D. Nangju, 1982. Plant density effects on growth, yield, leaf area index and light transmission on intercropped maize and cowpea in Nigeria. J. Agric. Sci., Camb., 99 : 10-23.

Fisher, N.M., 1977. Studies on mixed cropping. 1. Seasonal difference in relative productivity of crop mixtures and pure stands. Expl. Agric., 13 : 177-184.

Francis, C.A., C.A. Flor and S.R. Temple. 1976. Adapting varieties for intercropped systems in the tropics. In: Multiple cropping (Eds.) R.I. Papendick, P.A. Sanchez and G.B. Triplett. American Society of Agronomy, USA. p.235-254.

Francis, C.A., M. Praeger, and G. Tedjada. 1982. Effect of relative planting dates in beans and maize intercropping. Fd. crops Res., 5 : 45-54.

Galwey, N.W., M.A. De Queiroz and R.W. Willey. 1986. Genotypic variation in the response of sorghum to intercropping with cowpea and in the effect on the associated legume. *Fd. Crops Res.*, 14 : 263-290.

Gangwar, B. 1986. Studies on sorghum legume intercropping. *Indian J. Agron.* 31(4) : 407-408.

Gangwar, B. and G.S. Kalra. 1979. Studies on mixed cropping of legume with maize under rainfed conditions. *Madras agric. J.*, 66(7) : 425-429.

Gebrekidan, B., 1977. Sorghum legume intercropping in Ethiopia. Cowpeas - Abstract of World Literature, IITA, Ibadan, Nigeria, p. 136.

Gomez, K.A. and A.A. Gomez. 1981. Statistical procedures for agricultural research with emphasis on rice. IRRI, Los Banos, Philippines.

Guleria, W.S. and C.M. Singh. 1979. Effect of weed management on yield, economics and nutrient uptake in maize. *Indian J. Weed Sci.*, '11 : 53-58.

Hanchinal, R.R., A.F. Habib and J.V. Goud. 1979. Correlation and path analysis in cowpea. *Mysore J. agric. Sci.*, 13(3): 253-257.

Harper, J.L. 1963. The individual in the population. *J. Ecol.*, 52 : 149-158.

Hegde, D.M. and C.S. Saraf, 1979. Effect of intercropping and phosphorus fertilisation of pigeonpea on soil temperature and soil moisture extraction. *Indian J. Agron.*, 24(2): 217-220.

Henzel, E.F. and I. Vallis, 1977. Transfer of N between legumes and other crops. In: Biological nitrogen fixation in Farming systems of Tropics. (Eds.) A. Ayanala and P.J. Dart, John Wiley and Sons, New York, p. 73-88.

Hulugalle, N.R. and R. Lal. 1986. Soil water balance of intercropped maize and cowpea grown in a tropical hydromorphic soil in Western Nigeria. Agron. J., 78(1) : 86-90.

Humphries, E.C. 1956. Modern methods of plant analysis. Springer-Var-lag, Berlin. pp. 468-502.

ICRISAT, 1977. Annual Report, 1976-77, ICRISAT, Hyderabad, India.

ICRISAT, 1981. Annual Report, 1979-80, ICRISAT, Hyderabad, India.

ICRISAT, 1982. Annual Report, 1981. ICRISAT, Hyderabad, India.

ICRISAT, 1987a. Research highlights, 1987. ICRISAT, Hyderabad, India.

ICRISAT, 1987b. Annual Report, ICRISAT, Hyderabad. India pp.304-305.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Kanwar, J.S., T.J. Rego and N. Seetharama. 1984. Fertilizer and water use efficiency in pearl millet and sorghum in vertisols and alfisols of semiarid India. Fert. News, 29(4) : 42-52.

Kasam, A.H. 1976. Crops of the West African semiarid tropics. Annual Report, 1976, ICRISAT, Hyderabad, India. p. 37-40.

- Kibani, T.H.M., C.L. Keswani and M.S. Chowdhury. 1976. Rhizosphere population in intercropped maize and soybean. Proc. Symposium on intercropping in semiarid areas, Mar. 1976, Morogoro, Tanzania.
- Kitamura, Y. and S. Nashimura. 1979. Growth and N-fixation in cowpea-maize intercropping as affected by plant competition for light and nutrients. Cowpea - Abstract of World Literature, IITA, Ibadan, Nigeria, p. 140.
- Krantz, B.A. 1981. Intercropping on an operational scale in an improved farming system. Proc. International Workshop on Intercropping. Jan 1979, ICRISAT, Hyderabad, India. p. 318-327.
- Krishnan, A. 1988. Delineation of soil climatic zones of India and its practical application in agriculture. Fert. News, 33(4): 11-19.
- Krishnasamy, M. and SP. Palaniappan. 1979. Complimentary and competitive effects of associated crops in groundnut based intercropping system. Madras agric. J., 66 : 757-759.
- Kunasekaran, V., R. Jayaram, S.R. Chowdappan and U.S. Sreeramulu. 1980. Intercropping in rainfed sorghum. Madras agric. J., 67 : 816-818.
- Kuo, C.G., M.C. Jung and S.C.S. Tsou, 1978. Translocation of photosynthates in mungbean. Hort. Sci., 13 : 580.
- Lal, R. 1979. Modification of soil fertility characteristics by management of soil physical properties. In: Soil physical properties and crop production in Tropics. (Eds.). R. Lal and D.J.Greenland, John Wiley and Sons, Chichester, 1979, pp.397-405.

- Littleton, E.J., M.D. Dennett, J.L. Monteith and J. Gloston, 1979. Growth and development of cowpea under tropical conditions. *J. agric. Sci.*, 93(2) : 309-320.
- Madhavan, M., V.S. Shanmughasundaram and SP. Palaniappan. 1986. Effects of population on physiological growth parameters of pigeonpea genotypes in sole and intercropped stand with sorghum Co 22. *J. Agron. Crop Sci.*, 157 : 43-51.
- Mafra, R.C., M. de A. Lira, A.S.S. Arcoverde, G. Roberio and M.A. Faris, 1981. Studies on intercropping of sorghum and corn with beans and cowpea. *Proc. International Workshop on intercropping*, Jan 1979, ICRISAT, Hyderabad, India p. 46-51.
- Manickasundaram, P. 1978. Studies on sorghum based cropping systems under rainfed conditions. M.Sc. (Ag.) Dissertation, Dept. of Agronomy, TNAU, Coimbatore.
- Manickasundaram, P. and SP. Palaniappan, 1978. Studies on sorghum based cropping systems for dry farming conditions. *Sorghum Newsletter*, 21 : 64-65.
- Mc Gilchrist, C.A. 1965. Analysis of competition experiments. *Biometrics*, 21 : 975-985.
- Mead, R. and R.D. Stern. 1981. Statistical considerations in experiments to investigate intercropping. *Proc. International Workshop on intercropping*. Jan. 1979, ICRISAT, Hyderabad, India, p. 263-276.

- Miranda, S.M., P. Pathak and K.L. Srivatsava. 1983. Run-off management on small agricultural water sheds. The ICRISAT experience. In: Dryland Agricultural Research in India. Thrust in the Eighties, AICRPDA, Hyderabad, India, 1983. p. 88-97.
- Moody, K. 1978. Weed control in intercropping in Tropical Asia. International Weed Science Congress, July, 1978, IRRI, Los Banos, Philippines.
- Moody, K., and S.V.R. Shetty. 1981. Weed management in intercropping systems. Proc. International Workshop on intercropping, Jan 1979, ICRISAT, Hyderabad, India, P. 229-237.
- Nair, K.P., U.K. Patel, R.P. Singh and M.K. Kaushik, 1979. Evaluation of legume intercropping in conservation of fertilizer N in maize culture. J. agric. Sci., 93(1) : 189-194.
- Narain, P., Balvir Varma and A.K. Singhal. 1980. Nitrogen economics through intercropping of the pigeonpea in rainfed sorghum. Indian J. Agron., 25 : 190-196.
- Natarajan, M. and R.W. Willey. 1980. Sorghum-pigeonpea intercropping and the effects of plant population density. J. Agric. Sci., Camb., 95: 51-65.
- Natarajan, M. and R.W. Willey. 1981. Growth studies in sorghum-pigeonpea intercropping with particular emphasis on canopy development and light interception. Proc. International Workshop on Intercropping, Jan 1979, ICRISAT, Hyderabad, India. p. 180-187.

- Natarajaratnam, N., T. Venkateswara Rao and K. Balakrishnan. 1985. Path analysis of yield components of cowpea. Madras agric. J., 72(5) : 259-262.
- Ofori, F. and W.R. Stern. 1987. Relative sowing time and density of component crops in maize-cowpea intercrop system. Expl. Agric. 23 : 41-52.
- Olsen, S.R., C.V. Cole, F.S. Watanabe and D.A. Dean. 1954. Estimation of available P in soils by extraction with sodium bicarbonate. USDA Circular No. 939.
- Osiru, D.S.O. and R.W. Willey. 1972. Studies on mixtures of dwarf sorghum and beans with particular reference to plant population. J. agric. Sci., Camb., 79: 531-540.
- Palaniappan, SP., 1985. Cropping systems in the Tropics - Principles and Management. Wiley Eastern Limited., New Delhi. p.123.
- Pandey, R.P., P.K.R. Nair and J.P. Tiwari. 1981. Correlation of morpho-physiological and sink parameters in cowpea. Indian J. agric. Sci. 51 : 221-224.
- Panse, V.G. and P.V. Sukhatme. 1985. Statistical methods for agricultural workers, 4th ed., ICAR, New Delhi, 1985.
- Rajat De and S.P. Singh. 1981. Management practices for intercropping systems. Proc. International Workshop on Intercropping. Jan. 1979, ICRISAT, Hyderabad, India. p. 17-21.
- Ramakrishna, A. 1984. Studies on intercropping systems in rainfed lands under varying levels of fertility and moisture regimes, Thesis abstract, X(2) : 114.

- Rao, A.C.S. and S.K. Das. 1982. Soil fertility management and fertilizer use in dryland crops. In: A decade of Dryland Agricultural Research in India. 1971-80, AICRPDA, Hyderabad, India, 1982. pp.120-139.
- Rao, M.R. 1985. Improved cropping systems for semiarid regions of India. Paper presented at the Summer Institute on cropping system management, July, 1985, TNAU, Coimbatore, India.
- Rao, M.R. and S.V.R. Shetty. 1976. Some biological aspects of intercropping systems on crop weed balance. Indian J. Weed Sci., 8(1) : 32-43.
- Rao, M.R. and R.W. Willey. 1980. Evaluation of yield stability in intercropping studies with sorghum - pigeonpea. Expl. Agric., 16 : 105-116.
- Rao, M.R. and R.W. Willey. 1981. Stability of performance of a pigeonpea-sorghum intercrop system. Proc. International Workshop on intercropping, Jan 1979, ICRISAT, Hyderabad, India. p. 306-317.
- Rao, M.R. and R.W. Willey. 1983. Effects of genotypes in cereal pigeonpea intercropping on the alfisols of SAT of India. Expl. Agric., 19 : 67-78.
- Rao, M.R., T.J. Rego and R.W. Willey. 1987. Response of cereals to N in sole cropping and intercropping with different legumes. Plant and Soil, 101(2) : 167-177.
- Rao, N.G.P., B.S. Rana and P.P. Tarhalkar. 1981. Stability, productivity and profitability of some intercropping systems in dryland agriculture. Proc. International Workshop on Intercropping, Jan 1979, ICRISAT, Hyderabad, India. p.292-298.

- 64
- Reddy, M.S. and R.W. Willey. 1981. Growth and resource use studies in an intercrop of pearl millet/groundnut. *Fd. crops Res.*, 4: 13-24.
- Reddy, M.S., C.N. Floyd and R.W. Willey. 1980. Groundnut in intercropping systems. *Proc. International Groundnut Workshop*, Oct, 1980, ICRISAT, Hyderabad, India.
- Rees, D.J. 1986. The effects of population density and intercropping with cowpea on the water use and growth of sorghum in semiarid conditions of Botswana. *Agric. Forest Meteorology*, 37: 293-308.
- Rego, T.J. 1981. Nitrogen response studies of intercropped sorghum with pigeonpea. *Proc. International Workshop on intercropping*, Jan 1979, ICRISAT, Hyderabad, India. p. 210-216.
- Remison, S.U. 1978a. Neighbour effects between maize and cowpea at various levels of N. *Expl. Agric.*, 14 : 205-212.
- Remison, S.U. 1978b. Performance of cowpea as influenced by weed competition. *J. Agric. Sci.*, 90(3) : 523-530.
- Remison, S.U. 1982. Interaction between maize and cowpea sown simultaneously and at intervals in a forest zone of Nigeria. *Indian J. agric. Sci.*, 52 : 500-505.
- Ryan, J.G. and R. Sarin. 1981. Economics of technology options for vertisols in the relatively dependable rainfall regions of SAT. *Proc. Seminar on management of deep black soils*, May 1981, New Delhi. p. 37-58.

- Sahrawat, K.L., T.J. Rego and J.R. Burford. 1979. Work experience in rainfed farming at ICRISAT with special reference to fertilizer use. Proc. FAI Group discussion on fertilizer use in dry lands. pp. 21-30.
- Sahrawat, K.L., T.J. Rego and J.R. Burford. 1982. Work experience in rainfed farming system with special reference to fertilizer use. Tech. Bull., Farming systems Res. Programme. ICRISAT, Hyderabad, India.
- Saxena, N.P. and A.R. Sheldrake. 1979. Physiology of growth, development and yield of chickpeas in India. Proc. International workshop on chickpea improvement, Mar, 1979, ICRISAT, Hyderabad, India.
- Searle, P.G.E., Y. Comndom, D.C. Snedden and R.A. Nance. 1981. Effect of maize-legume intercropping systems and fertilizer N on crop yields and residual N. Fd. crops Res. 4 : 133-145.
- Selvaraj, S., 1978. Intercropping in rainfed sorghum. M.Sc.(Ag.) dissertation, Dept. of Agronomy, TNAU., Coimbatore, India.
- Shantaram, M.V. and G. Rangaswamy. 1967. A comparison of rhizosphere microflora of mixed crops. Mysore J. agric. Sci., 1: 7-12.
- Sharma, S., V.K. Rao and K. Vijayalakshmi. 1982. Soil and moisture conservation for drylands. In: A decade of Dryland Agricultural Research in India, 1971-80, ICAR, New Delhi. pp. 90-102.
- Shekhawat, M.S., J.J. Sharma and R.K. Sharma. 1983. Relative efficacy of herbicides for weed control in mungbean. Indian J. Weed Sci., 15(2) : 147-151.

- Shetty, S.V.R. and M.R. Rao. 1979. Weed management studies in pigeonpea based intercropping. Proc. 6th Asian Pacific Weed Science Society Congress, July, 1977. Jakarta, Indonesia, Vol.II, pp. 655-672.
- Shetty, S.V.R. and M.R. Rao. 1981. Weed management studies in sorghum-pigeonpea and pearl millet-groundnut intercropping systems. Proc. International Workshop on intercropping, Jan 1979, ICRISAT, Hyderabad, India. p. 238-248.
- Singh, B.P. 1985. Effect of intercropping with pearl millet on productivity, profitability and water use in aridisols. Indian J. Agron. 30(4) : 408-413.
- Singh, K.C. and R.P. Singh. 1977. Intercropping of annual grain legumes with sunflower. Indian J. agric. Sci. 47(11) : 563-567.
- Singh, R.P., K.C. Singh and Y.S. Ramakrishna. 1978. Effect of planting system of pearl millet on yield, total productivity and moisture use and monetary return. Indian J. Agric. Sci., 48 : 138-142.
- Singh, S.P. 1977. Intercropping and double cropping studies in grain sorghum. Proc. International sorghum workshop, March 1977, ICRISAT, Hyderabad, India.
- Singh, S.P., 1981. Studies on spatial arrangement in sorghum legume intercropping system. J. agric. Sci., Camb., 97 : 655-661.
- Singh, S.P. 1983. Planned intercropping can improve yields in small farms. International Agrl. Development, Jan - Feb, 1983, p. 8-10.

- 90
- Singh, S.P. and O.P. Jain. 1984. Stability studies in sorghum based intercropping systems under rainfed conditions in India. J. Agron. Crop Sci. 53 : 40-51.
- Singh, S.P. and D. Jha. 1984. Stability of sorghum based intercropping systems under rainfed conditions in India. Indian J. Agron., 29: 101-106.
- Snaydon, R.W. and P.M. Harris. 1981. Interactions below ground The use of nutrients and water. Proc. International Workshop on intercropping, Jan 1979, ICRISAT, Hyderabad, India. p.188-201.
- Soundararajan, D. and SP. Palaniappan. 1979. Effect of intercropping on growth and yield components of redgram. Indian J. agric. Res., 13 : 127-132.
- Spitters, C.J.T., 1983. An alternative approach to the analysis of mixed cropping experiments 2. Marketable yield. Netherlands J. agric. Sci., 31 : 143-155.
- Stickler, F.C., S. Wearden and A.W.Pauli, 1961. Leaf area determination in grain sorghum. Agron. J., 53 : 187-188.
- Stoop, W.A. 1981. Cereal based intercropping system for the West African SAT. Proc. International Workshop on Intercropping, Jan 1979, ICRISAT, Hyderabad, India, p. 61-68.
- Subbiah, B.V. and C.L. Asija. 1956. A rapid procedure for estimation of available nitrogen in soils. Curr. Sci. 25 : 259-260.

- Subramanian, S. and R. Kulandaivelu. 1986. Crop water requirement and irrigation scheduling - A guide for Tamil Nadu, Centre for soil and crop Management Studies, TNAU., Coimbatore, India.
- Szeicz, G. 1975. Solar radiation in crop canopies. J. Appl. Ecol., 12 : 1117-1156.
- Tarhalkar, P.P. and N.G.P. Rao. 1981. Genotype - plant density consideration in the development of an efficient intercropping system for sorghum. Proc. International Workshop on Intercropping, Jan 1979, ICRISAT, Hyderabad, India, p. 35-40.
- Thakur, R.C. and U.C. Bora, 1987. Effect of planting geometry in maize-blackgram intercropping system, Indian J. Agron., 32(1) : 91-92.
- Thangasamy, R. 1983. Effect of seed treatment, application of graded doses of N and intercropping cowpea on the growth and yield of rainfed sorghum Co 23. M.Sc. (Ag.) dissertation, Dept. of Agronomy, TNAU., Coimbatore. 1983.
- Thiagarajan, P. and S. Ramiah. 1984. Effect of planting method on grain yield and its attributes of rainfed sorghum varieties. Madras agric. J., 71(6) : 365-370.
- Tiwari, A.S., L.N. Yadav, L. Singh and C.N. Mahdik. 1977. Spreading plant type does better in pigeonpea. Bull. Trop. grain Legumes. 7 : 7-9.
- Tomer, P.S. and S.L. Saini. 1979. Crop geometry and intercropping in rainfed pearl millet. Indian J. agric. Sci., 49: 627-632.

- 22
- Trenbath, B.R. 1981. Light use efficiency of crops and the potential for improvement through intercropping. Proc. International Workshop on intercropping, Jan 1979, ICRISAT, Hyderabad, India. p. 141-154.
- Turk, K.J., A.E. Hall and C.W. Asbell, 1980. Drought adaptation of cowpea. Agron. J., 72(3) : 413-439.
- Umat, D.S. and S.L. Deshpande, 1985. Current effect of legume on sorghum. Sorghum Newsletter, 28 : 35.
- Umrani, N.K., S.H. Shinde and P.M. Dhonde. 1984. Studies on intercropping of pulses in Kharif sorghum. Indian J. Agron., 29(1) : 27-30.
- Uprety, D.C., O.P.S. Tomar and G.S. Sirohi. 1979. A note on the yield determining factors in cowpea varieties. Indian J. Plant Physiol. 22(2) : 156-159.
- Venkateswarlu, J. 1983. Nutrient supply from organic sources. In: Dryland Agricultural Research in India - Thrust in Eighties, AICRPDA, Hyderabad, India. p. 54-60.
- Venkateswarlu, J. 1985. Crops and cropping systems in dryland agriculture. In: Efficient management of dryland crops, CRIDA, Hyderabad, India. 1985. p. 1-16.
- Venkateswarlu, J. 1986. Efficient resource management for drylands In: 15 years of dryland Agricultural Research, CRIDA, Hyderabad, India. 1986, p. 42-58.
- Venkateswarlu, J. and I.P.S. Ahlawat, 1986. Studies on weed management in pigeonpea based intercropping systems. Indian J. Agron. 31(2) : 184-186.
- .

- 22
- Waghmare, A.B. and S.P. Singh. 1984. Sorghum legume intercropping and the effects of nitrogen fertilisation. I. Yield and nitrogen uptake. *Expl. Agric.*, 20 : 251-259.
- Wahab, K. 1978. Studies on the influence of season, water management and system of planting on the growth and yield of sorghum varieties. M.Sc. (Ag.) dissertation, Dept. of Agronomy, TNAU., Coimbatore, India.
- Wahua, T.A.T. 1983. Nutrient uptake by intercropped maize and cowpea and a concept of nutrient supplementation index. *Expl. agric.*, 19 : 263-275.
- Wien, H.C. and E.E. Ackah. 1978. Pod development period in cowpea. *Crop Sci.* 18(5) : 791-794.
- Wien, H.C. and D. Nangju. 1976. The cowpea as intercrop under cereals. Cowpea - Abstract of world Literature, IITA, Ibadan, Nigeria, p. 147.
- Wien, H.C. and J.B. Smithson. 1981. The evaluation of genotypes for intercropping. Proc. International Workshop on Intercropping, Jan 1979, ICRISAT, Hyderabad, India p.105-116.
- Wijesinha Anila, W.T. Federer, J.R.P. Carvalho and T. de Aquino Portes, 1982. Some statistical analyses for a maize and beans intercropping experiment. *Crop Sci.*, 22 : 660-666.
- Willey, R.W. 1979a. Intercropping - its importance and research needs. Part I - competition and yield advantages. *Fd. Crop Abstracts*, 32(1) : 1-10.

- Willey, R.W. 1979b. Intercropping - its importance and research needs. Part II - Agronomy and research approaches. *Fd. Crop Abstracts*. 32(2) : 73-85.
- Willey, R.W. 1981. A scientific approach to intercropping research. *Proc. International Workshop on Intercropping*, Jan 1979, ICRISAT, Hyderabad, India, p. 4-14.
- Willey, R.W. and D.S.O. Osiru. 1972. Studies on mixtures of maize and beans with particular reference to plant population. *J. Agric. Sci., Camb.*, 79 : 519-529.
- Willey, R.W. and M.R. Rao. 1977. Pearlmillet intercropping. *Proc. International pearlmillet workshop*, Sep 1977, ICRISAT, Hyderabad, India.
- Willey, R.W. and M.R. Rao. 1980. A competitive ratio for quantifying competition between intercrops. *Expl. Agric.*, 16 : 117-125.
- Willey, R.W. and M.R. Rao. 1981. Genotype studies at ICRISAT. *Proc. International Workshop on intercropping*, Jan 1979, ICRISAT, Hyderabad, India, p. 117-127.

APPENDICES

APPENDIX I

Weather during cropping period

Week	Temperature °C		R.H		Rainfall mm	Sunshine hours day ⁻¹	E _o mm day ⁻¹	ET _o mm day ⁻¹
	Max.	Min.	7.22	14.22				
1983-84								
35	32.4	23.0	86	51	-	4.9	6.2	4.0
36	31.1	22.6	87	58	3.5 (1)	4.1	5.4	4.0
37	29.6	22.2	86	66	50.5 (4)	3.3	2.2	3.8
38	29.9	22.2	83	63	2.0	3.8	5.1	3.8
39	31.9	22.0	74	50	-	9.2	8.3	4.7
40	31.9	21.4	80	50	-	7.4	7.1	4.0
41	33.2	19.9	81	40	-	9.8	7.8	5.0
42	31.4	21.8	89	56	61.4 (3)	5.3	3.4	3.0
43	29.6	21.8	90	64	39.4 (3)	4.1	2.2	3.0
44	29.1	21.4	90	64	179.4 (3)	5.4	1.3	3.2
45	29.7	19.2	87	58	5.0 (1)	8.0	3.8	3.2
46	29.9	17.8	86	46	-	9.7	4.2	4.1
47	30.2	20.1	88	49	-	7.6	3.9	4.5
48	29.2	19.9	84	55	3.4 (1)	7.0	3.3	3.5
49	27.6	20.8	88	61	22.0 (3)	6.3	2.9	3.5
50	29.3	21.3	86	52	-	5.8	4.7	3.6
51	27.3	20.2	88	59	18.5 (1)	3.0	2.8	2.5
52	27.7	21.5	94	73	95.8 (4)	4.3	1.1	2.6
1	28.0	20.5	87	58	-	7.2	3.7	3.4
2	27.2	19.3	85	54	-	5.2	3.9	2.5
3	28.6	21.1	89	58	10.0 (1)	6.2	4.2	3.5
4	29.6	17.1	87	44	-	8.9	5.3	4.3
5	29.2	19.2	89	45	-	6.7	4.4	4.3
6	28.1	20.5	93	55	6.6 (2)	5.2	2.4	3.0
7	28.8	21.4	92	63	37.2 (5)	4.1	3.0	3.1
8	31.7	21.0	88	48	-	9.9	5.0	5.0
9	35.7	22.4	93	40	7.4 (1)	7.2	6.1	5.2
1984-85								
35	31.4	21.7	77	46	-	7.3	8.4	5.8
36	32.3	21.1	86	45	-	8.4	7.0	5.9
37	31.9	21.7	77	41	-	9.0	7.2	5.9
38	32.3	22.3	89	57	12.0 (2)	6.0	3.2	4.0
39	30.7	21.6	93	63	70.6 (4)	4.4	2.4	4.0
40	24.6	22.0	91	74	152.9 (4)	3.3	2.2	3.0
41	29.1	20.9	83	54	32.0 (1)	8.4	5.3	4.0
42	30.5	16.6	83	38	-	11.0	6.1	5.3
43	30.2	21.0	91	59	144.0 (4)	6.5	3.1	3.0
44	29.4	20.1	89	52	18.7 (1)	10.3	3.3	4.0
45	29.3	20.5	93	53	51.0 (2)	8.0	2.6	3.8
46	29.8	20.3	89	57	17.5 (2)	6.7	2.9	3.9
47	28.7	20.1	84	53	-	5.7	3.4	2.5
48	28.3	17.5	87	59	36.5 (1)	5.0	3.1	2.4

(Figures in parantheses indicate rainy days)

207

APPENDIX I (CONTINUED)

Weather during cropping period

Week	Temperature °C		R.H		Rainfall mm	Sunshine hours day ⁻¹	E _o mm day ⁻¹	ET _o mm ^o day ⁻¹
	Max.	Min.	7.22	14.22				
49	27.8	18.7	92	52	4.0 (1)	8.9	2.8	3.3
50	29.2	13.6	90	35	-	10.3	4.2	4.9
51	28.3	14.5	90	39	-	10.4	4.3	4.9
52	30.9	19.3	89	43	-	9.9	4.5	5.2
1	27.6	21.3	92	71	70.4 (4)	3.7	1.2	2.8
2	28.5	19.1	89	52	-	8.5	3.5	3.5
3	28.2	19.6	88	51	-	6.5	3.7	3.5
4	29.5	17.5	88	39	-	9.9	4.9	5.0
5	31.3	18.8	88	38	-	7.9	5.1	5.0
6	32.0	16.7	73	36	-	6.5	4.7	5.0
7	32.6	21.0	85	38	-	9.1	5.0	5.0
8	32.3	18.4	72	32	-	9.6	5.3	4.9
9	34.8	18.7	80	22	-	10.9	6.8	5.0
1985-86								
35	30.9	21.7	93	62	14.0 (1)	6.7	5.3	5.1
36	31.9	21.4	96	51	5.0 (1)	5.6	5.3	5.0
37	31.8	21.0	88	54	-	7.9	6.8	4.6
38	32.5	20.9	91	52	14.0 (1)	7.3	7.0	4.8
39	30.4	21.3	95	61	79.9 (6)	5.8	3.6	3.8
40	29.8	22.0	95	78	58.0 (1)	6.0	4.8	3.2
41	31.1	21.1	94	52	8.0 (1)	6.8	6.2	3.2
42	31.6	20.5	95	57	8.1 (1)	7.5	4.9	4.5
43	30.6	20.5	86	50	18.0 (1)	8.3	4.9	5.0
44	29.8	21.1	82	58	-	4.3	4.3	3.1
45	26.4	21.1	95	84	17.5 (1)	1.3	1.0	2.9
46	29.0	19.9	93	62	1.2	6.6	3.0	3.0
47	30.0	19.5	91	56	12.0 (1)	6.8	3.8	3.0
48	28.3	16.5	85	53	-	8.2	4.3	3.0
49	28.4	20.3	86	54	8.8 (1)	3.9	3.4	3.0
50	29.7	20.1	86	54	0.5	6.9	3.8	3.2
51	29.2	17.5	90	45	-	8.6	4.4	4.1
52	29.7	18.1	86	40	-	8.0	4.9	4.2
1	29.3	17.0	81	35	-	9.8	5.0	5.0
2	28.3	20.2	84	56	-	1.6	3.7	2.9
3	28.9	20.2	88	46	38.0 (1)	7.4	3.0	4.5
4	29.6	17.0	86	40	-	9.5	5.4	5.0
5	31.1	19.4	81	38	-	9.5	4.7	5.6
6	31.0	20.0	78	41	-	4.0	5.4	4.3
7	31.3	20.8	84	44	1.0	7.6	5.5	5.2
8	31.7	19.0	83	42	3.2 (1)	8.7	5.5	5.1
9	31.7	19.4	81	32	1.0	9.0	6.1	5.1

R.H. _ Relative humidity; E_o - Panevaporation
 ET_o - Reference crop evapotranspiration

201

APPENDIX II

Estimated soil moisture balance

Days after sowing (1)	Initial moisture (mm/60 cm) (2)	Rainfall mm (3)	Crop ET mm (4)	Estimated balance (mm/60 cm) (mm/30 cm) (5) (6)		Effective rainfall mm (7)
Sorghum Co 25 based cropping systems (1983-84)						
1	75.6	-	-	75.6	36.3	-
5	75.6	1.0	5.2	71.4	35.4	1.0
8	71.4	11.2	3.1	79.5	39.4	11.2
9	79.5	12.0	1.0	90.5	44.9	12.0
10	90.5	15.2	1.0	97.7	48.4	8.2
11	97.7	24.0	1.1	97.7	48.4	1.1
12	97.7	58.4	1.1	97.7	48.4	1.1
15	97.7	12.0	3.4	97.7	48.4	3.4
16	97.7	28.0	1.1	97.7	48.4	1.1
17	97.7	57.0	1.1	97.7	48.4	1.1
19	97.7	1.0	2.2	96.5	47.9	1.0
20	96.5	4.0	1.1	97.7	48.4	2.9
40	97.7	2.4	53.2	46.9	23.3	2.4
42	46.9	1.0	5.6	42.3	21.0	1.0
46	42.3	8.4	8.4	42.3	21.0	8.4
47	42.3	8.0	2.8	47.5	23.6	8.0
48	47.5	5.6	2.8	50.3	24.9	5.6
55	50.3	-	19.8	30.5	15.1	-
60	30.5	-	14.9	15.6	7.7	-
65	15.6	1.5	12.5	4.6	2.3	1.5
66	4.6	17.0	2.5	19.1	9.5	17.0
67	19.1	12.5	2.6	29.0	14.4	12.5
68	29.0	5.0	2.6	31.4	15.6	5.0
69	31.4	73.0	2.6	97.7	48.4	68.9
70	97.7	3.8	2.6	97.7	48.4	2.6
72	97.7	1.5	5.2	94.0	46.6	1.5
80	94.0	-	25.6	68.4	33.9	-
90	68.4	10.0	13.9	64.5	32.0	10.0
100	64.5	-	19.4	45.1	22.4	-
111	45.1	2.0	22.3	24.8	12.3	2.0
112	24.8	2.0	1.5	25.3	10.5	2.0
113	25.3	10.8	1.5	34.6	17.2	10.8
114	34.6	1.8	1.5	34.9	17.3	1.8
118	34.9	1.0	6.1	29.8	14.8	1.0
119	29.8	1.2	1.5	29.5	14.6	1.2
120	29.5	-	1.5	28.0	13.9	-
		392.3	254.3			207.3

(contd.)

957

Sorghum Co 22 based cropping systems (1983-84)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	75.6	-	-	75.6	37.5	-
5	75.6	1.0	5.2	71.4	35.4	1.0
8	71.4	11.2	3.1	79.5	39.4	11.2
9	79.5	12.0	1.0	90.5	44.9	12.0
10	90.5	15.2	1.0	97.7	48.4	8.2
11	97.7	24.0	1.1	97.7	48.4	1.1
12	97.7	58.4	1.1	97.7	48.4	1.1
15	97.7	12.0	3.4	97.7	48.4	3.4
16	97.7	28.0	1.1	97.7	48.5	1.1
17	97.7	57.0	1.1	97.7	48.4	1.1
19	97.7	1.0	2.2	96.5	47.8	1.0
20	96.5	4.0	1.1	97.7	48.4	2.3
40	97.7	2.4	53.2	46.9	23.3	2.4
42	46.9	1.0	5.6	42.3	21.0	1.0
46	42.3	8.4	8.4	42.3	21.0	8.4
47	42.3	8.0	2.8	47.5	23.6	8.0
48	47.5	5.6	2.8	50.3	24.9	5.6
50	50.3	-	5.6	44.7	22.2	-
60	44.7	-	34.7	10.0	5.0	-
65	10.0	1.5	12.5	*	*	1.5
66	*	17.0	2.5	14.5	7.2	17.0
67	14.5	12.5	2.6	24.4	12.1	12.5
68	24.4	5.0	2.6	26.8	13.3	5.0
69	26.8	73.0	2.6	97.2	48.2	73.0
70	97.2	3.8	2.6	97.7	48.4	3.1
72	97.7	1.5	5.2	94.0	46.6	1.5
75	94.0	-	8.6	85.4	42.3	-
80	85.4	-	8.5	76.9	38.1	-
90	76.9	10.0	13.9	73.0	36.2	10.0
100	73.0	-	19.4	53.6	26.6	-
103	53.6	-	6.4	47.2	23.4	-
		373.5	224.7			192.5

210

APPENDIX II (CONTINUED)

Sorghum Co 25 based cropping systems (1984-85)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	49.0	-	-	49.0	24.3	-
2	49.0	5.4	1.4	53.0	26.3	5.4
4	53.0	10.4	2.8	60.6	30.1	10.4
5	60.6	5.2	1.4	64.4	31.9	5.2
8	64.4	15.0	4.2	75.2	37.3	15.0
9	75.2	38.0	1.4	97.7	48.4	23.9
10	97.7	2.0	1.4	97.7	48.4	1.4
11	97.7	13.0	1.0	97.7	48.4	1.0
13	97.7	29.9	2.0	97.7	48.4	2.0
14	97.7	98.0	1.0	97.7	48.4	1.0
15	97.7	12.0	1.0	97.7	48.4	1.0
18	97.7	22.0	3.5	97.7	48.4	3.5
20	97.7	-	2.8	94.9	47.1	-
35	94.9	31.0	52.1	73.8	36.6	31.0
36	73.8	5.2	2.4	76.6	38.0	5.2
37	76.6	62.0	2.4	97.7	48.4	23.5
38	97.7	16.2	2.4	97.7	48.4	2.4
39	97.7	1.0	3.2	95.5	47.4	1.0
44	95.5	1.5	16.0	81.0	40.2	1.5
45	81.0	16.2	3.2	94.0	46.6	16.2
46	94.0	28.0	3.0	97.7	48.4	6.7
47	97.7	23.0	3.0	97.7	48.4	3.0

Contd.

211

(1)	(2)	(3)	(4)	(5)	(6)	(7)
55	97.7	-	24.6	73.1	36.2	-
58	73.1	3.5	11.7	64.9	32.2	3.5
59	64.9	14.0	3.9	75.0	37.2	14.0
60	75.0	-	2.5	72.5	36.0	36.5
73	72.5	36.5	29.8	79.2	39.3	4.0
74	79.2	4.0	3.3	79.9	39.6	-
80	79.9	-	19.8	60.1	29.8	-
88	60.1	-	19.5	40.6	20.1	-
100	40.6	-	30.3	10.3	5.1	-
104	10.3	8.2	8.0	10.5	5.1	8.2
105	10.5	34.2	1.4	43.3	21.5	34.2
106	43.3	22.0	1.4	63.9	31.7	22.0
107	63.9	6.0	1.4	68.5	34.0	6.0
120	68.5	-	22.0	46.5	23.1	-
		563.4	292.6			288.7

Sorghum Co 22 based cropping systems (1984-85)

1	49.0	-	-	49.0	24.3	-
2	49.0	5.4	1.4	53.0	26.3	5.4
4	53.0	10.4	2.8	60.6	30.1	10.4
5	60.6	5.2	1.4	64.4	31.9	5.2
8	64.4	15.0	4.2	75.2	37.3	15.0

Contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
9	75.2	38.0	1.4	97.7	48.4	23.9
10	97.7	2.0	1.4	97.7	48.4	1.4
11	97.7	13.0	1.0	97.7	48.4	1.0
13	97.7	29.9	2.0	97.7	48.4	2.0
14	97.7	98.0	1.0	97.7	48.4	1.0
15	97.7	12.0	1.0	97.7	48.4	1.0
18	97.7	22.0	3.5	97.7	48.4	3.5
20	97.7	-	2.8	94.9	47.1	-
35	94.9	31.0	52.1	73.8	36.6	31.0
36	73.8	5.2	2.4	76.6	38.0	5.2
37	76.6	62.0	2.4	97.7	48.4	23.5
38	97.7	16.2	2.4	97.7	48.4	2.4
39	97.7	1.0	3.2	95.5	47.4	1.0
44	95.5	1.5	16.0	81.0	40.2	1.5
45	81.0	16.2	3.2	94.0	46.6	16.2
46	94.0	28.0	3.0	97.7	48.4	6.7
47	97.7	23.0	3.0	97.7	48.4	3.0
50	97.7	-	9.1	88.6	43.9	-
58	88.6	3.5	37.0	55.1	27.3	3.5
59	55.1	14.0	3.9	65.2	32.3	14.0
60	65.2	-	2.5	62.7	31.1	-
73	62.7	36.5	31.8	67.4	33.4	36.5

Contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
74	67.4	4.0	3.3	68.1	33.8	4.0
75	68.1	-	3.3	64.8	32.1	-
80	64.8	-	8.2	56.6	28.1	-
88	56.6	-	15.6	41.0	20.3	-
100	41.0	-	30.3	10.7	5.3	-
101	10.7	-	2.6	8.1	4.0	-
102	8.1	-	2.6	5.5	2.7	-
103	5.5	-	1.4	4.1	2.0	-
104	4.1	8.2	1.4	10.9	5.4	8.2
		501.2	264.6			225.0

Sorghum Co 25 based cropping systems (1985-86)

1	56.5	-	-	56.5	27.2	-
2	56.5	3.0	1.3	58.2	28.9	3.0
3	58.2	13.4	1.3	70.3	34.9	13.4
4	70.3	57.0	1.1	97.7	48.4	57.0
5	97.7	1.0	1.1	97.6	48.3	1.0
16	97.6	8.0	12.3	93.3	46.3	8.0
20	93.3	-	5.8	87.5	43.4	-
23	87.5	7.5	10.8	84.2	41.8	7.5

Contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
24	84.2	0.6	3.6	81.2	40.3	0.6
30	81.2	18.0	24.0	75.2	37.2	18.0
39	75.2	8.6	23.7	60.1	29.8	8.6
40	60.1	35.0	2.3	92.8	46.0	35.0
41	92.8	19.2	2.3	97.7	48.4	7.2
42	97.7	29.4	2.3	97.7	48.4	2.3
43	97.7	23.0	2.3	97.7	48.4	2.3
46	97.7	1.2	7.0	91.9	44.6	1.2
55	91.9	-	21.6	70.3	34.9	-
56	70.3	12.0	3.0	79.3	39.3	12.0
67	79.3	7.5	33.0	53.8	26.7	7.5
72	53.8	0.5	15.0	39.3	19.5	0.5
73	39.3	-	3.0	36.3	18.0	-
80	36.3	0.5	22.4	14.4	7.1	0.5
82	14.4	-	4.1	10.3	5.1	-
100	10.3	-	39.5	*	*	*
110	*	37.5	17.3	*	*	37.5
114	*	0.5	9.0	*	*	0.5
116	*	-	4.5	*	*	-
		283.4	273.6			223.1

25

Sorghum Co 22 based cropping systems (1985-86)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	56.5	-	-	56.5	27.2	-
2	56.5	3.0	1.3	58.2	28.9	3.0
3	58.2	13.4	1.3	70.3	34.9	13.4
4	70.3	57.0	1.1	97.7	48.4	57.0
5	97.7	1.0	1.1	97.6	48.3	1.0
16	97.6	8.0	12.3	93.3	46.3	8.0
20	93.3	-	5.8	87.5	43.4	-
23	87.5	7.5	10.8	84.2	41.8	7.5
24	84.2	0.6	3.6	81.2	40.3	0.6
30	81.2	18.0	24.0	75.2	37.3	18.0
39	75.2	8.6	23.7	60.1	29.8	8.6
40	60.1	35.0	2.3	92.8	46.0	35.0
41	92.8	19.2	2.3	97.7	48.4	7.2
42	97.7	29.4	2.3	97.7	48.4	2.3
43	97.7	23.0	2.3	97.7	48.4	2.3
46	97.7	1.2	7.0	91.9	45.6	1.2
50	91.9	-	9.6	82.3	40.8	-
56	82.3	12.0	18.0	76.3	37.8	12.0
67	76.3	7.5	33.0	50.8	25.2	7.5
72	50.8	0.5	15.0	36.3	18.0	0.5
73	36.3	-	3.0	33.3	16.5	-

Contd.

076

(1)	(2)	(3)	(4)	(5)	(6)	(7)
75	33.3	-	6.4	26.9	13.3	-
80	26.9	0.5	8.0	19.4	9.6	-
82	19.4	-	4.1	15.3	7.6	0.5
100	15.3	-	39.5	*	*	-
101	*	-	2.5	*	*	-
102	*	-	2.5	*	*	-
103	*	-	1.4	*	*	-
		245.4	244.2			185.6